Science Indicators 1974

National Science Board
1975

NATIONAL SCIENCE BOARD
(as of 1975)

Science Indicators Unit

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Science Indicators 1974

Report of the National Science Board 1975

National Science Board
National Science Foundation

Letter of Transmittal

December 10, 1975

My Dear Mr. President:

I have the honor of transmitting to you, and through you to the Congress, the Seventh Annual Report of the National Science Board. The Report is submitted in accordance with Section 4(g) of the National Science Foundation Act of 1950, as amended.

In this Report, *Science Indicators—1974*, the Board presents the second step in the process begun with *Science Indicators—1972* of developing indicators of the state of science in the United States. Our goal is a periodical series of indices of the strengths and weaknesses of science and technology in the United States and the changing character of that activity. We hope that by contributing to the understanding of science itself we will strengthen its forward thrust, illuminate its significance, and assist in the examination of its problems.

The indicators in this Report deal primarily with resources—human and financial—for research and development. Progress has been made in developing measures of the outcomes or impacts of research and development and the contributions made thereby to the welfare of the Nation. We are continuing as a high priority our study of indicators of the characteristics of science and technology and will describe our progress in successive Science Indicator reports.

Respectfully yours,

Norman Hackerman
Chairman, National Science Board

The Honorable
The President of the United States

Contents

Introduction

The National Science Board is charged by the Congress with providing an annual report of the status of science in the United States.[1] In this, its seventh report, the Board continues the development of a series of indicators assessing the condition of the Nation's scientific endeavor. These indicators are intended to measure and to reflect U.S. science—to demonstrate its strengths and weaknesses and to follow its changing character.

Indicators such as these, updated regularly, can provide early warnings of events and trends which might impair the capability of science—and its related technology—to meet the needs of the Nation. The indicators can also assist those who set priorities for the enterprise, allocate resources for its functions, and guide it toward change and new opportunities. In these ways, communication about the issues of science is facilitated and considerations of new areas of public policy can be explored.

The internal characteristics of science provide the most readily available data for indicators, including the human and financial resources involved, the education of research scientists, changes in the institutional structures which support research and development, advances in the fundamental understanding of science and the transfer of technology. Of equal importance are measures of the external impact of science, often called "output indicators". These indicators are difficult to devise because the translation of science into technology and the genesis of science in technological advances are both deeply embedded among complex economic and social variables. In addition, many of the applications of science are not immediately realized, occurring long after and often appearing unrelated to their origins in research. However, the present report represents an advancement in the development of indicators of the outputs of the research and development enterprise.

The establishment of a comprehensive system of science indicators involves the investigation of potential indices, expansion of the underlying data base, improvement of methods for measuring the impacts of science and technology, development of analytic approaches for interpreting the measures, and demonstration of their utility across several audiences.

The effort to develop a system of effective indicators should be regarded as a long-term process. A central concept of the effort is, therefore, an evolving set of indicators derived from continuing exploration, testing, and design. The set will be evaluated, expanded, refined, and updated regularly as new data become available, as our understanding of their nature improves, and as the science enterprise itself changes.

Quantitative indicators are not a substitute for the experience and judgment of the scientific community. Indices, at their best, can only serve as supplements. The interpretation of indicators themselves—what they mean for the present and the future of the enterprise—requires the participation of the scientific community.

The Report

Indicators in this report include measures of basic research activity and industrial R&D, indices of scientific and engineering personnel and institutional capabilities, indicators of productivity and the U.S. balance of trade in high-technology products, and other aspects of the Nation's science and engineering activities.

Compared to the first Science Indicators report of the National Science Board,[2] the present report contains substantially more indicators, expanded to fill some of the major gaps and reorganized to present a more current and integrated coverage of science and related technology. A new chapter discusses industrial R&D in the United States, and includes the results of a survey on the innovative process. Additions to other portions of the report provide new information on the role of basic science in advancing technology, international aspects of technological innovation, and changing attitudes of the public toward science.

These indicators of the scientific enterprise are presented in six chapters, generally with a time span beginning in the early 1960's and

[1] Section 4(g) of the National Science Foundation Act as amended by Public Law 90-407.

[2] *Science Indicators—1972*, National Science Board (NSB 73-1).

extending through 1974 where possible. Data which appeared in *Science Indicators—1972* for earlier years are repeated here to encourage longitudinal comparisons and to make it unnecessary to refer to the previous report. Most of the indicators are presented in graphical form and are numbered to correspond with the numerical data tables in the Appendix. Each of the chapters is introduced by an "Indicator Highlights" section which briefly summarizes the major indices of that chapter. It should be noted that these highlights often omit important caveats and discussion contained in the text itself. The original data sources, many of which are publications of the Division of Science Resources Studies, National Science Foundation, are indicated throughout the report. Staff of the Division also took part in the development of charts and text.

The challenge faced in creating and using indicators of complex social systems such as science and technology is substantial, and the present efforts to assess U.S. science are still only in the early stages of maturity. Appreciation is due to the Social Science Research Council which, with NSF support, convened a seminar in 1974 on science indicators and which has recently established a Subcommittee on Science Indicators. The reports to follow in this series will aim to sharpen concepts, refine their treatment, and seek new measures of the state of science. It is hoped that all those interested in science indicators will participate in the search.

International Indicators of Science and Technology

International Indicators of Science and Technology

INDICATOR HIGHLIGHTS

- The proportion of the Gross National Product (GNP) spent for R&D has declined steadily over the last decade in the United States, while growing substantially in the U.S.S.R., West Germany, and Japan; in 1973, the fraction of GNP directed to R&D was 2.4 percent in the United States, compared with 3.1 percent for the U.S.S.R., 2.4 percent for West Germany, and 1.9 percent for Japan.[1]

- The number of scientists and engineers engaged in R&D per 10,000 population declined in the United States after 1969 but continued to grow in all other countries studied; by 1973, this number was 25 per 10,000 for the United States, 18 for West Germany, 19 for Japan (1971), and 37 for the U.S.S.R.[1]

- All major R&D-performing countries reduced their proportion of government R&D expenditures for national defense between 1961 and the early 1970's, while either maintaining or expanding expenditures for the advancement of science and economic development; the United States had the largest fraction of expenditures for national defense and the smallest for the latter two areas throughout the period. (Data for the U.S.S.R. are not available).

- The United States was the largest producer of the scientific literature sampled throughout the 1965-73 period in all fields except chemistry and mathematics, where its share was second to that of the U.S.S.R.; in recent years, however, U.S. research publications in the fields of chemistry, engineering, and physics have declined slightly in both absolute and relative terms.

- Citation indices of U.S. scientific research equal or exceed those of other major research-performing countries based on a large sample of the 1973 literature; the United States ranked highest in the fields of chemistry and physics.

- U.S. scientists have received a larger overall number of Nobel Prizes in the sciences (physics, chemistry, and physiology-medicine) than any other country; awards to U.S. scientists, however, declined after the 1951-60 decade, primarily as the result of fewer prizes for research in physics.

- The United States had a favorable but declining "patent balance" between 1966 and 1973; the decline of 30 percent was due primarily to increases in the number of patents awarded by the United States to Japan and West Germany, and to decreases in patents granted to the United States by Canada and the United Kingdom.

- A majority of a sample of major technological innovations of the past twenty years were produced by the United States; the proportion of innovations of U.S. origin, however, declined from a high of 80 percent in the late 1950's to some 55-60 percent since the mid-1960's, while other countries—particularly Japan and West Germany—increased their shares.

- The United States had an increasingly positive balance of payments from the sale of technical "know-how" (patents, licenses and manufacturing rights) over the 1960-73 period, with four to five times more technical "know-how" sold to other nations than purchased from them; the rising net receipts to the United States were due largely to purchases by Japan after the mid-1960's.

- The level of U.S. productivity (Gross Domestic Product per employed civilian)

[1] Data regarding the U.S.S.R. should be treated as gross estimates; limited information and differences in basic definitions make international comparisons involving the U.S.S.R. particularly tenuous. (See the following text for discussion of this point).

exceeded that of the other major R&D-performing nations between 1960-74, although gains in productivity were larger in the latter countries; by 1974, the productivity of France and West Germany was some 75-80 percent of the U.S. level, while Japan, with the largest gains in productivity, reached a level which was approximately 55 percent as high as U.S. productivity.

- The United States has a large, favorable balance of trade in commodities produced by R&D-intensive industries, in contrast to the increasingly negative balance in non-R&D-intensive products; the 1974 balance in R&D-intensive products was large enough to offset petroleum imports for the same year.

- The favorable U.S. trade balance in R&D-intensive products depends primarily upon exports to developing nations and to Western Europe; a deficit balance developed with Japan in the mid-1960's and continued through 1973, due largely to imports in the areas of electrical machinery, professional and scientific instruments, and nonelectrical machinery.

This chapter presents indicators of science and technology in an international context. The focus is on the United States and how it compares with other major developed nations in several aspects of science and technology.

The indicators are directed primarily to four general aspects. The first of these relates to the absolute and relative levels of national resources utilized for research and development (R&D); this includes both human and financial resources, as well as the areas of application to which the R&D is aimed. The second topic centers around scientific research; the indicators here deal principally with the quantity and quality of scientific research in individual countries and the international dimensions of science. The third facet concerns the output from applied R&D and technological efforts; indices in this group include trends in invention and innovation, and international transactions in technology. Finally, the fourth aspect deals with productivity, economic competitiveness, and international trade; indicators in this area provide measures of the level and change in the productivity of nations and of the role of R&D in the U.S. trade balance.

International indicators of science and technology suffer from several general deficiencies. There is usually a paucity of data; the reliability of the data which are available is often unknown or less than desired; and information is frequently based upon concepts and methods which may differ substantially among countries. These place restrictions on both the aspects of science and technology which can be measured and the accuracy of the measurements themselves. For these reasons, the indicators and international comparisons presented in this chapter should be interpreted with considerable caution.

RESOURCES FOR R&D

The international comparisons presented here are based upon indicators of the human and financial resources directed to R&D by the major R&D-performing countries. These indicators are limited to measures of the magnitude of the national resources for R&D, and the general areas to which they are directed (e.g., defense, space, and health).

Expenditures for R&D

R&D expenditures as percentages of the Gross National Product (GNP) are shown in figure 1-1 for the six countries with the largest R&D expenditures.[2] This indicator expresses the proportion of a country's economic output which is directed to R&D and is a measure of the R&D intensiveness of a nation.[3] But because of differences among countries in the composition,

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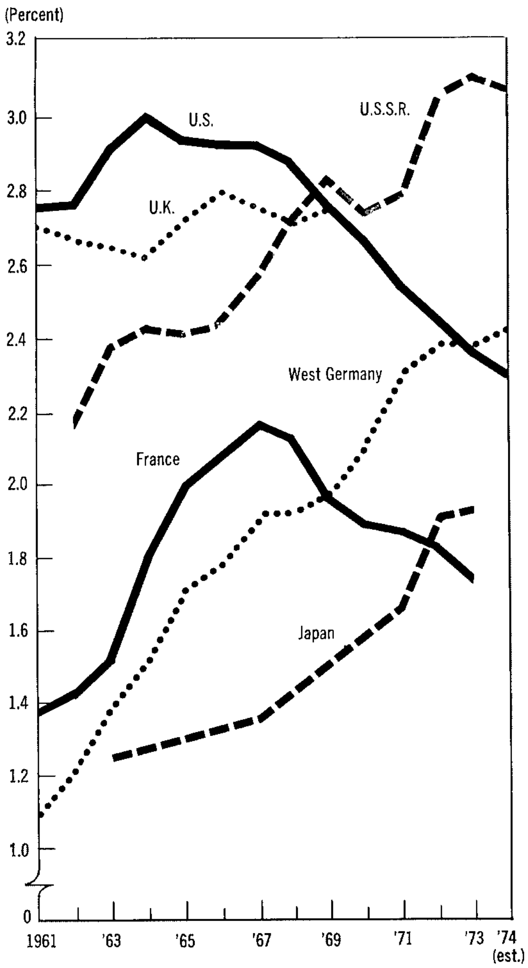
[2] Expenditures reported for the U.S. and the U.S.S.R. are for the performance of R&D alone, while those for other countries include associated capital expenditures.

[3] For the classification of various countries according to their R&D intensiveness, see "A Comparative Study of Science Advisory Approaches of Selected Developed Countries" in *Federal Policy, Plans, and Organization for Science and Technology, Part II,* U.S. Congress, House Committee on Science and Astronautics, 93rd Congress, 2nd Session, 1974.

Figure 1-1
R&D Expenditures as a Percent of Gross National Product (GNP), by Country, 1961-74



SOURCE: Organisation for Economic Co-operation and Development; individual country sources; U.S.S.R. estimates by Robert W. Campbell, Indiana University.

cost, and effectiveness of R&D—as well as inconsistencies in GNP accounting—the measure is relatively gross. Interpretations of the indicator, therefore, should focus on general trends rather than specific numerical values.

The fraction of the GNP of the United States devoted to R&D has declined steadily over the last 10 years, falling nearly one-fourth from its peak level in 1964. The decline, as discussed elsewhere in this report,[4] is due primarily to reduced growth of expenditures by the Federal Government for R&D in the defense and space areas; increases in R&D funds from all other sources combined kept pace with growth in the GNP. In the case of France, the only other country of those studied which showed a long-term decline in this indicator, the reduction appears to result largely from a slower growth in government R&D expenditures for national defense and nuclear energy.

Both Japan and West Germany recorded substantial growth in the proportion of the GNP directed to R&D. Underlying their growth were continuous large increases in R&D funding from both industry and government. Total R&D expenditures by Japan increased at an average annual rate of 21 percent between 1963 and 1973, and those of West Germany by 15 percent, as compared with 6 percent for the United States. More recently, annual increases between 1969-73 averaged 24 percent for Japan, 16 percent for West Germany, and 4 percent for the United States. While industry is the prime source of R&D funds in Japan and West Germany, funds provided by the government have grown relatively more than those from industry. Government funds for R&D in these two countries are concentrated on advancement of science and, to a lesser extent, on general economic growth and nuclear energy.[5]

For the U.S.S.R. this indicator is based upon limited information and should be regarded only as an estimate. The general upward trend in the proportion of the GNP devoted to R&D is believed to be valid, although the specific numerical values may differ significantly from the true values. Possible differences in the variety of activities regarded as R&D, as well as differences in GNP accounting, make international comparisons involving the U.S.S.R. particularly hazardous.

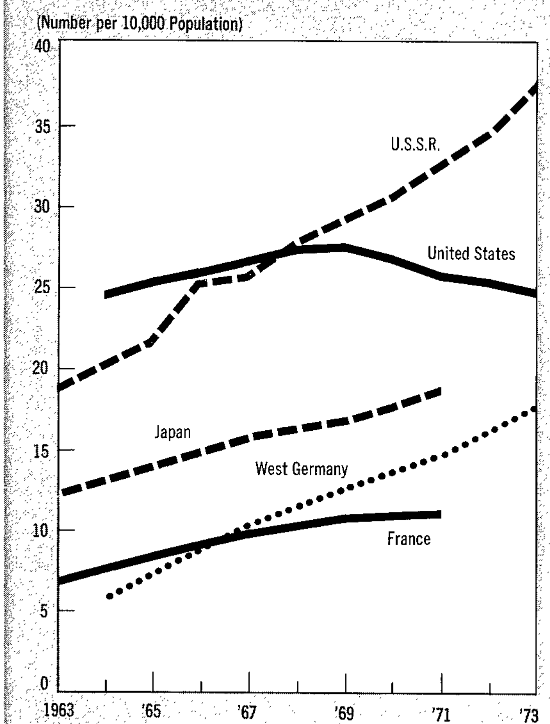
R&D Personnel

The human resources involved in R&D provide another comparison of the magnitude of national R&D efforts. The number of scientists

[4] See the chapter in this report entitled "Resources for R&D".

[5] Information on the distribution of government R&D expenditures among these and other areas is presented in a later section of this chapter.

Figure 1-2
Scientists and Engineers[1] Engaged in R&D per 10,000 Population, by Country, 1963-73



[1] Includes all scientists and engineers (full-time equivalent basis). Data for the United Kingdom are not available.
SOURCE: Organisation for Economic Co-operation and Development; U.S.S.R. estimates by Robert W. Campbell, Indiana University.

and engineers in R&D per 10,000 population is shown in figure 1-2 for the United States, the U.S.S.R., Japan, West Germany, and France. (Data for the United Kingdom are not available.) This indicator should be treated only as an approximate measure of the level and intensity of R&D because it fails to account fully for certain factors, such as national variations in the designation of scientists and engineers and their productivity.

The United States is the only major R&D-performing nation in which this indicator declined over the period studied.[6] For each of the other countries, the number of scientists and engineers engaged in R&D increased at a faster rate than the population. The United States is also unique among these nations in that a decline occurred in the number of scientists and engineers involved in R&D; this number fell from 558,000 in 1969 to 523,000 in 1973.[7] By comparison, the estimated number of such personnel in the U.S.S.R. increased from approximately 700,000 in 1969 to more than 900,000 in 1973. (See Appendix table 1-2.)

[6] The U.S. decline is due in large part to decreases in the employment of scientists and engineers in space and defense-related R&D. See the "Industrial R&D and Innovation" chapter of this report for further details.

Government-funded R&D

Governments provide funds for R&D in a variety of areas such as national defense, space exploration, public health, and economic development. The distribution of funds among these areas indicates the relative emphases of the R&D programs of different countries.

Government expenditures for R&D are classified by the Organisation for Economic Co-operation and Development (OECD) into the following categories:

National Defense, encompassing all R&D directly related to military purposes, including space and nuclear energy activities of a military character;

Space, including all civilian space R&D such as manned space flight programs and scientific investigations in space;

Nuclear Energy, consisting of all civilian R&D primarily concerned with nuclear sciences and technology;

Economic Development, which covers R&D in a wide range of fields including: agriculture, forestry, and fisheries; mining and manufacturing; transportation, communications, construction, and utilities;

Health, encompassing R&D in all of the medical sciences, and in health service management;

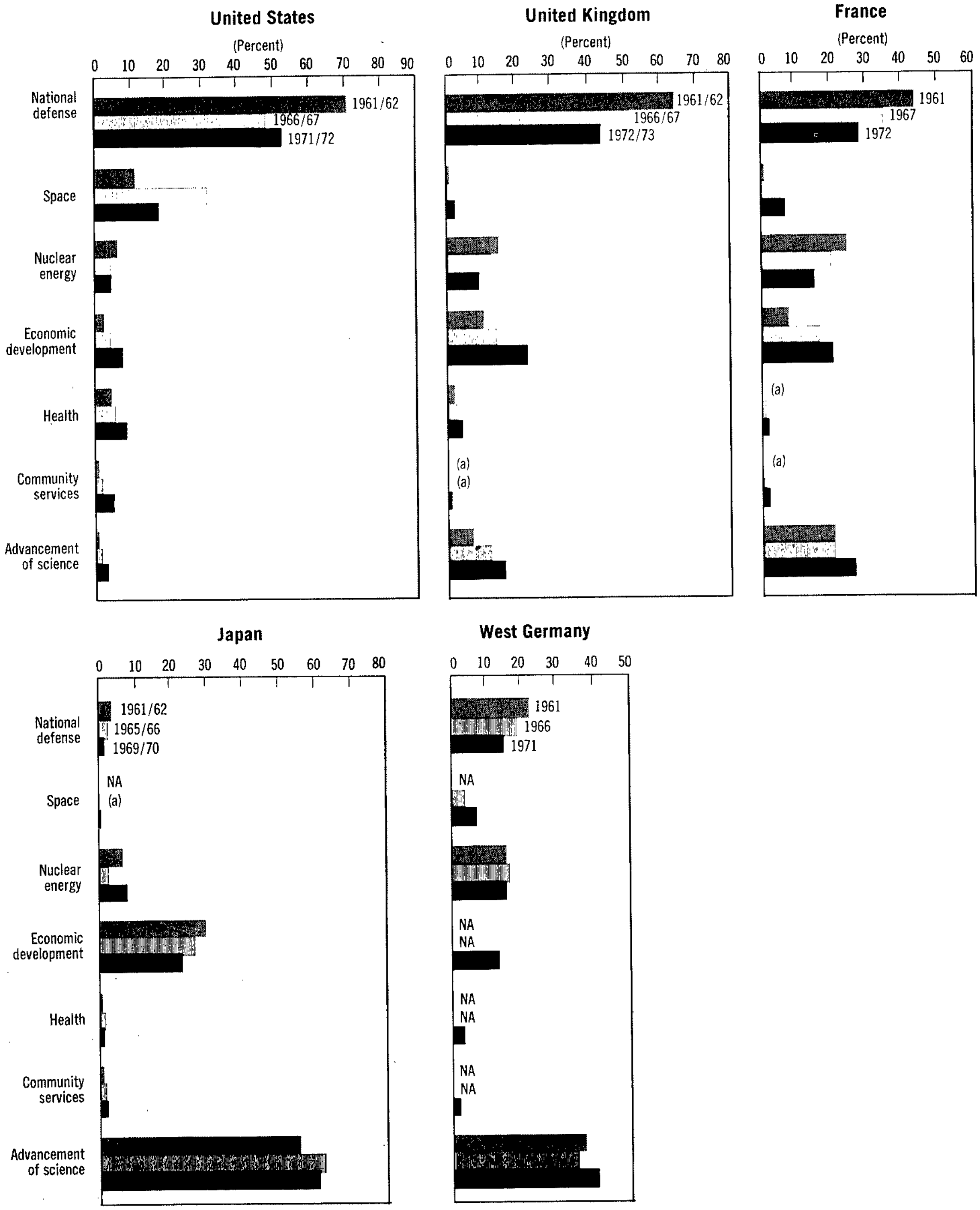
Community Services, which includes R&D for such purposes as pollution control, education, social services, disaster prevention, planning and statistics; and

Advancement of Science, consisting of funds for fundamental research in government and private laboratories, and for research and science instruction in universities.

[7] For more current data, see the chapter in this report entitled "Resources for R&D".

Figure 1-3

Distribution of Government R&D Expenditures among Areas by Country, 1961-73



(a) Less than 0.5 percent.
SOURCE: Organisation for Economic Co-operation and Development.

The percentage of total government funds going to each of these areas is shown in figure 1-3.[8] The United States differs principally from other nations in the relatively large percentage of R&D funds channeled to defense and space exploration (71 percent in 1971-72, the latest years for which such data are available for international comparisons), and the small percentages for the advancement of science and economic development.[9] In general, government R&D funds in other countries (except the United Kingdom) were concentrated in the latter two areas; this applied particularly to Japan and West Germany.

Changes in the distribution of government-funded R&D over the 1961-71 period were similar for each country. Defense-related R&D decreased as a proportion of the total R&D expenditures, whereas the fraction for the advancement of science and economic development generally increased, as did the percentage for health and community services. Overall trends suggest a relative shift from military R&D to areas of domestic concern and the advancement of science. (The magnitude of R&D expenditures for national defense, however, increased in absolute terms in all countries other than Japan.)

Differences between countries in the distribution of their R&D efforts arise from a variety of factors, such as the extent of a nation's military commitments and variations in the roles of government and the private sector. The pattern of R&D expenditures shown in figure 1-3 is based upon funding by governments only and does not include the large expenditures by the private sector, due to the lack of comparable data.

SCIENTIFIC RESEARCH

This section presents indicators of the international character of science and various measures of the magnitude and quality of scientific research in major nations. Indicators of magnitude are based upon the number of research publications from each nation in several fields of science. Quality indicators are developed from the international pattern of citations associated with these publications, as well as from the distribution of Nobel Prizes among nations and scientific fields.

The internationalism of science

Science by its very nature is international. The phenomena studied, the methods of investigation, and the validity of research findings are independent of national boundaries. Researchers from all countries can contribute to the body of scientific knowledge, with contributions assessed on their scientific merit, not the country of their origin.

The internationalism of science is based upon and fostered by a wide variety of formal and informal arrangements. Foremost among these are the publication of research findings in widely circulated journals and books, international meetings, joint research efforts, and informal correspondence among scientists. In addition to these, governments frequently sponsor international travel for scientists to consult and collaborate on research, and enter into formal bilateral agreements for scientific cooperation and exchange among nations. The international scientific community is also served by the International Council of Scientific Unions, which encompasses an array of associations for the advancement of science and the exchange of information. Finally, the United Nations has created specialized scientific agencies nearly global in scope, which foster international cooperation in science and which in turn provide models for similar regional organizations.

International scientific literature. The international dimension of science may be seen in one of its more fundamental forms in the performance of research and the publication of its results. Current research builds upon the extant body of scientific knowledge, which is the combined product of researchers from all countries. The dependence upon research performed in other nations is expressed, approximately, by a large sample of the citations in published research reports to scientific literature of foreign origin.

This indicator is shown in figure 1-4 for eight major fields of science and engineering, as well as for all the fields combined.[10] The indicator is based upon data from the six major R&D-performing nations identified in previous sec-

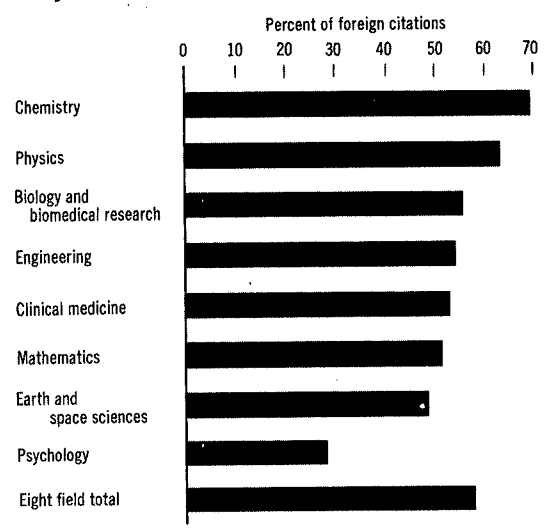
[8] Data are not available for the U.S.S.R.

[9] For current information on the distribution of U.S. Government expenditures for R&D, see the chapter in this report entitled "Resources for R&D"

[10] *Indicators of the Quantity and Quality of the Scientific Literature,* Computer Horizons, Inc., 1975 (A study commissioned specifically for this report).

Figure 1-4

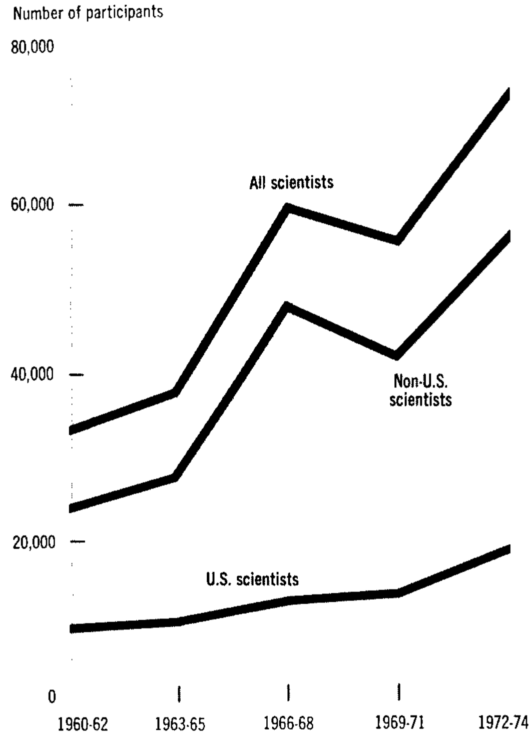
Percent of the Citations in Scientific Literature[1] Citing Countries Other than the Author's Own Country, by Selected Fields,[2] 1973



[1] Based on articles in 2,121 journals in the 1973 **Science Citation Index** from the U.S., United Kingdom, West Germany, France, U.S.S.R., and Japan.
[2] See Appendix table 7a for the description of fields. The social sciences are excluded because comparable data are not available.
SOURCE: Computer Horizons, Inc.

Figure 1-5

Participation in International Scientific Congresses by the United States and Other Countries, 1960-74



SOURCE: National Academy of Sciences.

tions. The figure shows that almost 60 percent of all citations in the scientific literature of these countries, for the eight fields as a whole, were to research of foreign origin.

Participation in international congresses. International meetings provide opportunities for scientists to exchange information and ideas through personal contact with foreign researchers. Among these are the international scientific congresses of those organizations constituting the International Council of Scientific Unions.

The numbers of scientists from the United States and from other nations who have attended these congresses in recent years are shown in figure 1-5. Although the attendance of U.S. scientists has increased throughout the period, attendance of foreign scientists has grown even more rapidly. In the 1972-74 period, non-U.S. scientists represented 75 percent of all participants. (Peaks in the attendance patterns are due to the larger number of congresses held in certain years).

Scientific literature

Research reports published in scientific and technical journals are one of the more direct outputs of scientific effort.[11] Such reports add to the body of scientific knowledge and may stimulate further research. The findings of the research, in addition, may be used in a variety of practical applications, many of which are unanticipated at the time the research is done. Although the reports may vary considerably in their theoretical and practical importance, the critical review which usually precedes publica-

[11] For discussions of publications as measures of the output of science, see: G. Nigel Gilbert and Steve Woolgas, "The Quantitative Study of Science: An Examination of the Literature", *Science Studies* Vol. 4 (1974), pp. 279-294; Henry Menard, *Science: Growth and Change* (Cambridge: Harvard University Press, 1971); and Derek J. deSolla Price, *Little Science, Big Science* (New York: Columbia University Press, 1963).

tion helps to ensure that the reports have some degree of scientific or technical significance.

Indicators based on research reports, however, have several limitations when used for international comparisons: the quantity of such reports may be influenced substantially by the journals selected for examination,[12] by national customs regarding the publishing of research papers, by the availability of funds for preparing and printing papers, by journal refereeing and publishing policies, etc. These and other limitations provide good reason for caution in interpreting such indicators.

The indicators presented in this section provide measures of: (1) the proportion of the world's research literature in selected scientific areas produced by the United States and other major research-performing countries; (2) the distribution of research literature among fields of science in each country; and (3) the influence of the literature produced in each field by each country.

National origins of scientific literature. Estimates of the literature produced by researchers in each country were based upon counts of articles, letters, and notes published in some 500 journals covered by the *Science Citation Index (S.C.I.)*[13] over the period 1965-73, supplemented by data from various abstracting services.[14] The journals included in the set were those which were most highly cited in the total 1965 literature, regardless of field. The national origin of the literature was determined by the country of the first author of each scientific paper. The results are presented in figure 1-6.[15]

The United States produced a larger proportion of the 1973 scientific literature in this sample of 492 journals than any other country in these fields: physics, engineering, psychology, molecular biology, and systematic biology. In the fields of chemistry and mathematics, however, the U.S.S.R. led all countries, with the United States following as the second largest producer.[16] The overall position of the United States, relative to the other countries, has changed little since 1965, the initial year of this indicator. For the seven fields as a whole, U.S. scientists and engineers published more than did those of any other country, followed by Soviet scientists and engineers. The United Kingdom, in these terms, ranks a distant third, while France, West Germany, and Japan cluster at a somewhat lower level.

The international position of the United States may be declining in the fields of chemistry, engineering, and physics. The U.S. share of the literature in each of these fields declined slightly in both 1972 and 1973, as shown in figure 1-6. Furthermore, the absolute number of publications in these areas was lower in 1973 than in some previous years.[17] (These declines may be related to trends in the funding of research in the three fields, as presented in the "Basic Research" chapter of this report).

Although attention was focused above on the six countries producing the largest number of scientific publications, several other nations contribute significantly to the world literature.[18] The largest contributors among these in 1973 were:

Australia	Italy
Canada	Netherlands
Czechoslovakia	Poland
India	Sweden
Israel	Switzerland

Each of these countries ranked among the first 10 nations in the number of 1973 research publications of at least one of the eight fields of science.

National research profiles. Countries differ in the emphasis they place on various fields of scientific research. The relative number of

[12] The representativeness of a journal set only approximates the representativeness of the articles themselves because of the varying sizes of journals and other reasons. The next *Science Indicators* report will examine this representiveness in detail.

[13] Published by the Institute for Scientific Information, Philadelphia, Pennsylvania.

[14] For details of the sample and methodology employed, see *Indicators of the Quantity and Quality of the Scientific Literature*, Computer Horizons, Inc., 1975. (A study commissioned specifically for this report).

[15] An analysis of 2,121 journals included in the *Science Citation Index* for 1973 yields similar results in the ranking of nations within fields, but comparable data for the larger set of journals are not available for earlier years.

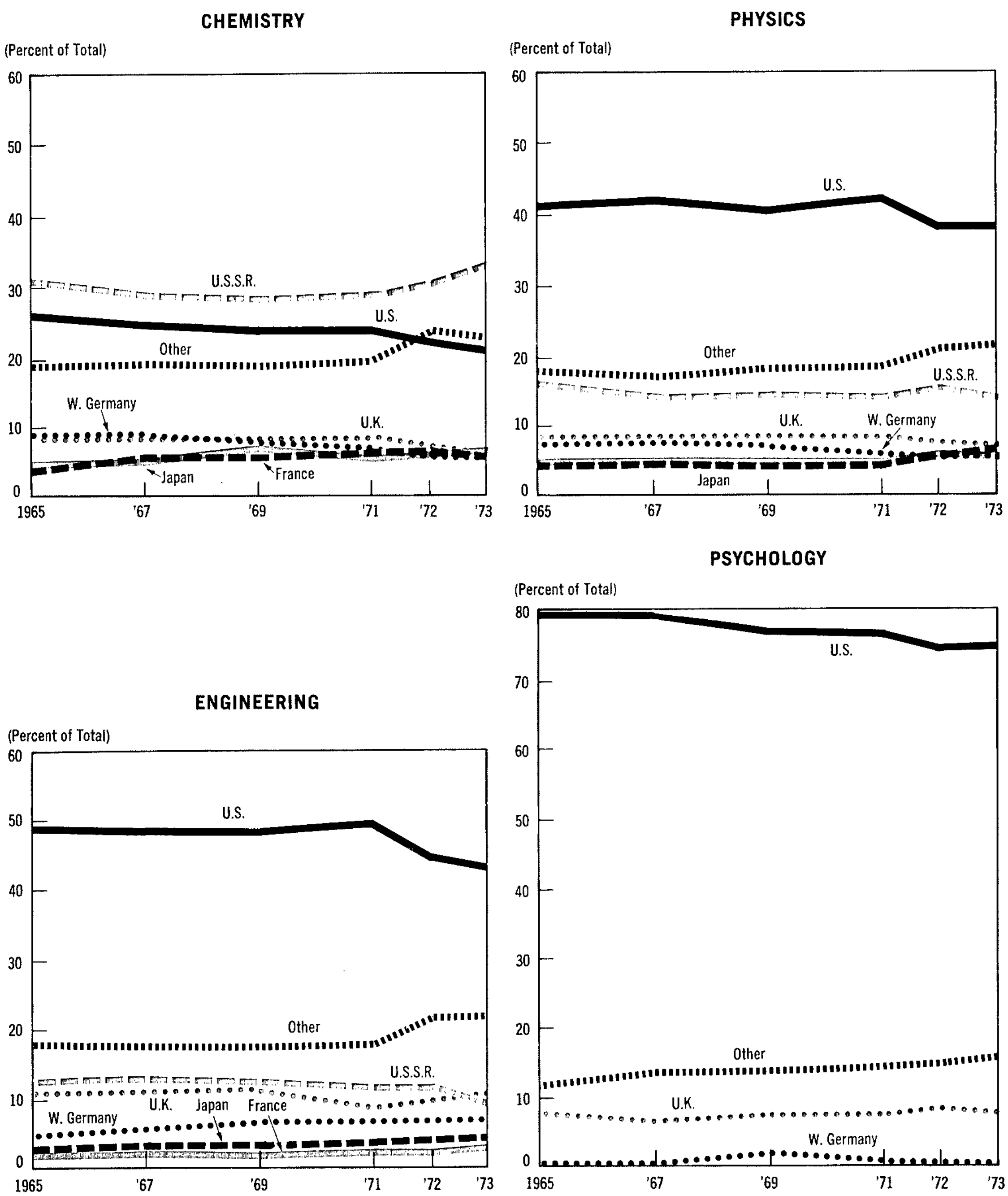
[16] The *Science Citation Index* for 1973 and earlier years did not include a number of important U.S.S.R. chemistry journals; the U.S.S.R. share of the chemistry literature, therefore, may be underestimated.

[17] Similar publication trends in these fields, found in another study, are presented in the "Basic Research" chapter of this report.

[18] These and all subsequent data on scientific literature were developed from an analysis of 2,121 of the journals in the 1973 *Science Citation Index*, as described in *Indicators of the Quantity and Quality of the Scientific Literature*, Computer Horizons, Inc., 1975 (A study commissioned specifically for this report).

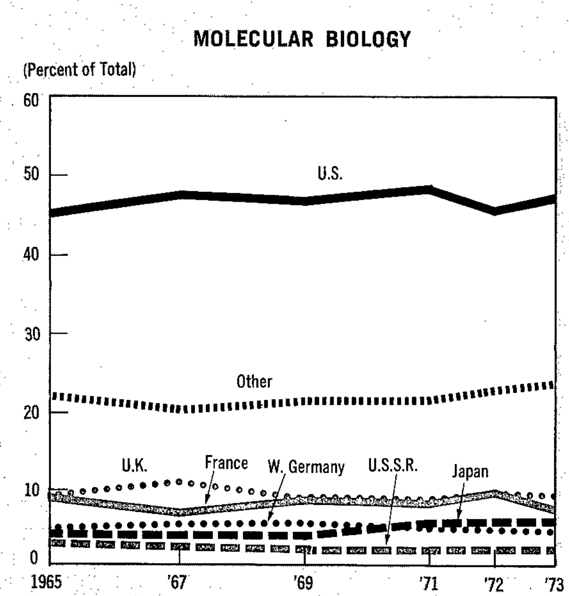
Figure 1-6

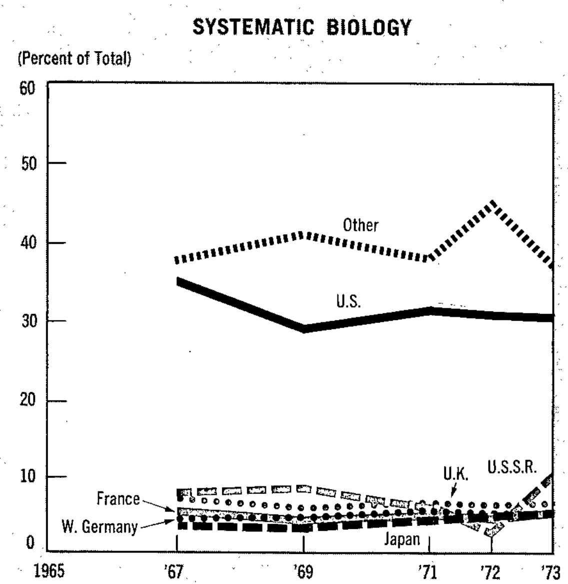
Scientific Literature[1] in Selected Fields[2] as a Percent of Total Literature, by Country, 1965-73

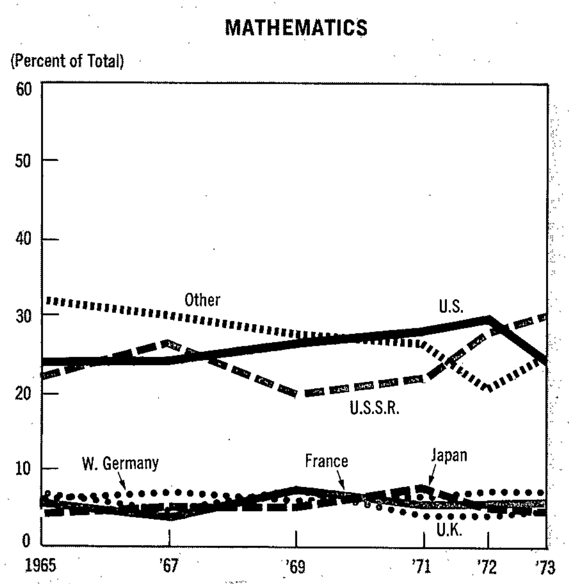


[1] Includes articles, letters and notes from the 492 scientific journals which were most heavily cited in 1965.
[2] The social sciences are excluded because comparable data were not available.
SOURCE: Computer Horizons, Inc.

Figure 1-6 continued







SOURCE: Computer Horizons, Inc.

publications in each field provides an approximate profile of a country's research effort. These 1973 profiles, based on the 278,894 *S.C.I.* publications in seven fields,[19] are shown in figure 1-7.[20] For purposes of comparison, the profile of publications produced by all countries combined is shown also.

The 1973 profile of the United States was most similar to that of West Germany and the United Kingdom in the relative proportion of the total literature in each field, although chemistry was emphasized somewhat more by the latter two countries. The profile of France's scientific research also resembles the United States, except for a smaller proportion of engineering research on the part of France and a larger fraction of literature in chemistry.

The country with the profile which differs most from that of the United States in the literature studied appears to be the U.S.S.R. The life sciences (biology, biomedical research, and clinical medicine) represent nearly 55 percent of the U.S. literature compared with just over 20 percent of the Soviet scientific and technical literature; conversely, engineering and the physical sciences (chemistry and physics) account for some 20 percent of the U.S. literature whereas the U.S.S.R. published almost 60 percent of its literature in these fields.

Literature citations. The significance of a nation's scientific literature is more important than mere counts of publications. One indicator of quality is the recognition that the research reported was dependent on published accounts of earlier investigations. Such a "citation index" is based on the belief that the most significant literature will be more frequently cited. In support of this assumption are a number of studies which demonstrate high correlations between citation counts and other measures of scientific importance, such as judgments of researchers in the field.[21]

The quality of scientific research is far more difficult to measure than its quantity. The use of citation indicators is one such approach, but one which requires considerable caution. Some articles may fail to be noticed because scientists do not have access to them, although this characteristic of the availability of a nation's scientific literature is itself an important aspect of the internationalism of science. Articles may be heavily cited only for the criticisms they provoke, or because they deal with minor improvements in methodology. Authors in some countries may cite only a few outstanding references for reasons such as journal space limitations, while similar scientists in other countries may give more complete citations. The particular choice of a sample of journals to be examined can have an effect on international comparisons if countries do not have appropriate representation in the sample. Because some nations concentrate more on applied research than on basic research, they may be underrepresented in the scientific literature.

The data source for this indicator was the *Science Citation Index*, as augmented for improved coverage of certain fields and countries, comprising 2,121 journals—virtually all of those included in the *S.C.I.* for 1973. The index was created by comparing the actual fraction of the world's total citations in a given field with the expected proportion based on that nation's share of the total publications in that field.

The resulting citation indices are shown in the table below for six fields. An index of 1.0 means that there were as many citations to a country's literature in the field as would be expected from its share of the world's publications; a larger index indicates a proportionally higher level of citation to the literature produced by a country than could be accounted for simply by the volume of its publications.

[19] These data employ a somewhat different taxonomy of fields of science than that used for the 492-journal set; see Appendix table 1-7a for the detailed taxonomy of the fields described in *Indicators of the Quantity and Quality of the Scientific Literature*, Computer Horizons, Inc., 1975.

[20] Because of the way this broad sample was selected, some fields may be understated, such as Russian mathematics. However, the scope of the *Science Citation Index* is determined by a 20-member, international editorial board consisting of two Soviet scientists; one is an expert in the information and documentation sciences area, the other is a mathematician. In recent years, the *Science Citation Index* has been expanded to include 90 percent of the 1,000 journals most highly cited by articles in some 2,100 journals and 100 percent of the 575 most highly cited.

[21] See "Citation Analysis: A New Tool for Science Administrators", *Science*, Vol. 188 (1975), pp. 429-432; Jonathan R. Cole and Stephen Cole, *Social Stratification in Science*, (Chicago: University of Chicago Press, 1973); Eugene Garfield, "Citation Analysis as a Tool in Journal Evaluation", *Science*, Vol. 178 (1972), pp. 471-478; J. Margolis, "Citation Indexing and Evaluation of Scientific Papers", *Science*, Vol. 155 (1967), pp. 1213-1219; and C. Roger Myers, "Journal Citations and Scientific Eminence in Contemporary Psychology", *American Psychologist*, Vol. 25 (1970), pp. 1041-1048.

Citation indices of selected scientific literature[22] by selected fields and countries, 1973

Field	Country	Citation indices
Clinical medicine	United States	1.3
	United Kingdom	1.3
	Japan	.6
	West Germany	.5
	France	.5
	U.S.S.R.	.2
Biology and biomedical research	United States	1.3
	United Kingdom	1.2
	Japan	.8
	West Germany	.8
	France	.6
	U.S.S.R.	.3
Chemistry	United States	1.5
	West Germany	1.5
	United Kingdom	1.4
	Japan	.7
	France	.7
	U.S.S.R.	.4
Physics	United States	1.4
	West Germany	1.0
	United Kingdom	.9
	France	.8
	Japan	.7
	U.S.S.R.	.6
Engineering	France	1.1
	United States	1.1
	United Kingdom	1.0
	U.S.S.R.	1.0
	West Germany	.9
	Japan	.8
Earth and space sciences	United States	1.3
	United Kingdom	1.0
	Japan	.7
	West Germany	.7
	France	.6
	U.S.S.R.	.3

The United States ranks first or ties for first place on this measure in each of the eight fields. The U.S. lead is greatest in physics, followed by the earth and space sciences.

Each country tends to have higher citation indices for its own scientific literature than it has for the literature of other countries (see Appendix table 1-7b). This is particularly true for the U.S.S.R. and France. The United States, on the other hand, cites its own literature less than other countries cite theirs, except in the fields of chemistry and physics where its domestic citation indices are higher than those of the other five countries.

Nobel Prizes in science

International prizes for scientific achievement, although awarded to individuals rather than countries, provide a gross indication of the relative position of nations in scientific research. Foremost among such awards are the Nobel Prizes. These prizes were established by a bequest of Alfred Bernhard Nobel, and give international recognition to achievements in the fields of physics, chemistry, and physiology/medicine.[23]

The Nobel Prizes from the first year awarded, 1901, are shown in figure 1-8 in terms of the number awarded to scientists in each of five countries which together account for a majority of the awards, and in relationship to the population of these countries.[24] Data are presented by year of award which, on the average, is some 15 years after the time of the research itself.

Scientists in the United States have received the largest number of awards over the 1901-74 period as a whole, surpassing all other countries since the 1931-40 decade. Prizes going to the U.S. scientists, however, declined after the 1951-60 decade, primarily as a result of a smaller number of prizes in the field of physics. In relationship to population, however, U.S. scientists received a smaller fraction of prizes than the United Kingdom over the last three decades.[25]

[22] The relatively high citation ratios associated with the United States and the United Kingdom may reflect, in part, the growing use of English as the language of scientific publication. Nevertheless, when citations made by U.S. and U.K. authors were excluded from these indices, the United States still had the highest citation ratios for chemistry, physics, mathematics, and the earth and space sciences.

[23] *Nobel, the Man and His Prizes.* (Stockholm: Nobel Foundation, 1962). Nobel also established prizes in the fields of literature and peace. Later, in 1969, the Nobel Foundation instituted the prize in economics and since then, 4 prizes have been awarded to U.S. economists, and single prizes to economists in Austria, the Netherlands, Norway, Sweden, and the United Kingdom. In some other areas of science which are not within the scope of the Nobel Prizes, there are similar international distinctions awarded for eminent accomplishments; for example, the Fields Medal for Mathematics was established in 1936 and since that time, U.S. mathematicians have received 35 percent of the quadrennial awards, largely after 1958.

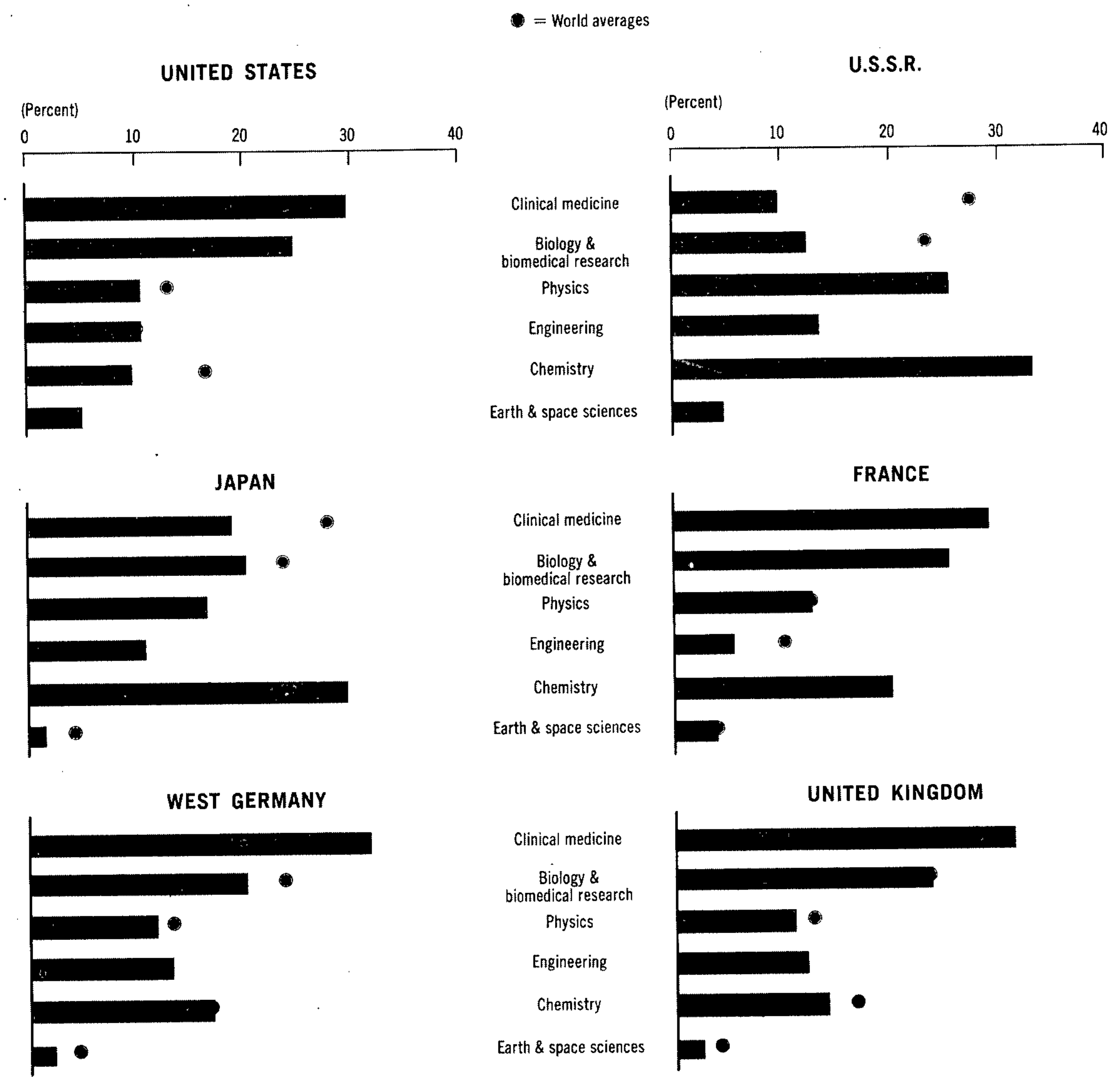
[24] The apparent decline in 1971-74 is partially explained by the shorter time interval covered in this period.

[25] Other countries, such as the Netherlands and Switzerland, have received a greater number of Nobel Prizes in respect to population size than either the United Kingdom or the United States.

The number of awards in individual fields of science are presented in figure 1-9. Over the 1901-74 period as a whole, the United States has the largest total number of awards in physics and in physiology/medicine, and is surpassed only by Germany in the number of prizes received in chemistry. In the most recent period, 1971-74, the United States received 56 percent of the awards in physics, 57 percent of those in chemistry, and 44 percent of those in physiology/medicine. These represent a smaller fraction of the prizes in each category than was received by the United States in the 1951-60 period.

Figure 1-7

Percent Distribution of Scientific Literature[1] by Selected Field,[2] for Each Country, 1973



[1] Includes articles, letters and notes from a sample of 2,121 journals.
[2] The social sciences are excluded because comparable data were not available.
SOURCE: Computer Horizons, Inc.

Figure 1-8 a

Nobel Prizes Awarded in Science, for Selected Countries, 1901-1974

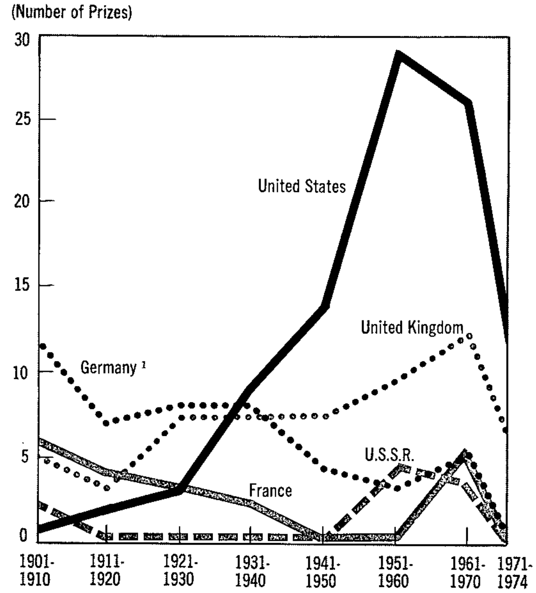
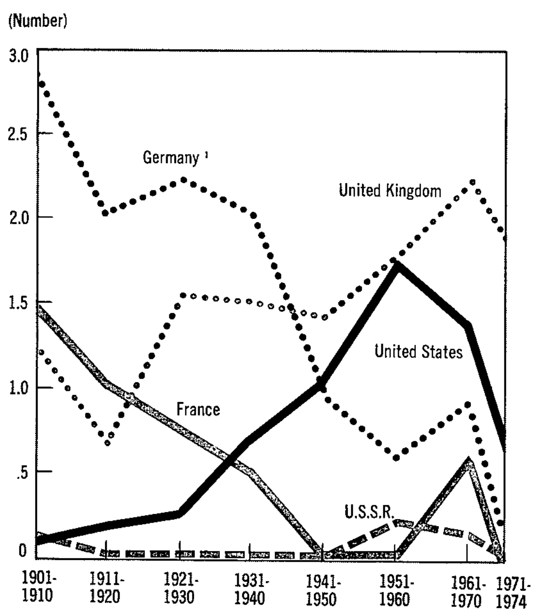


Figure 1-8 b

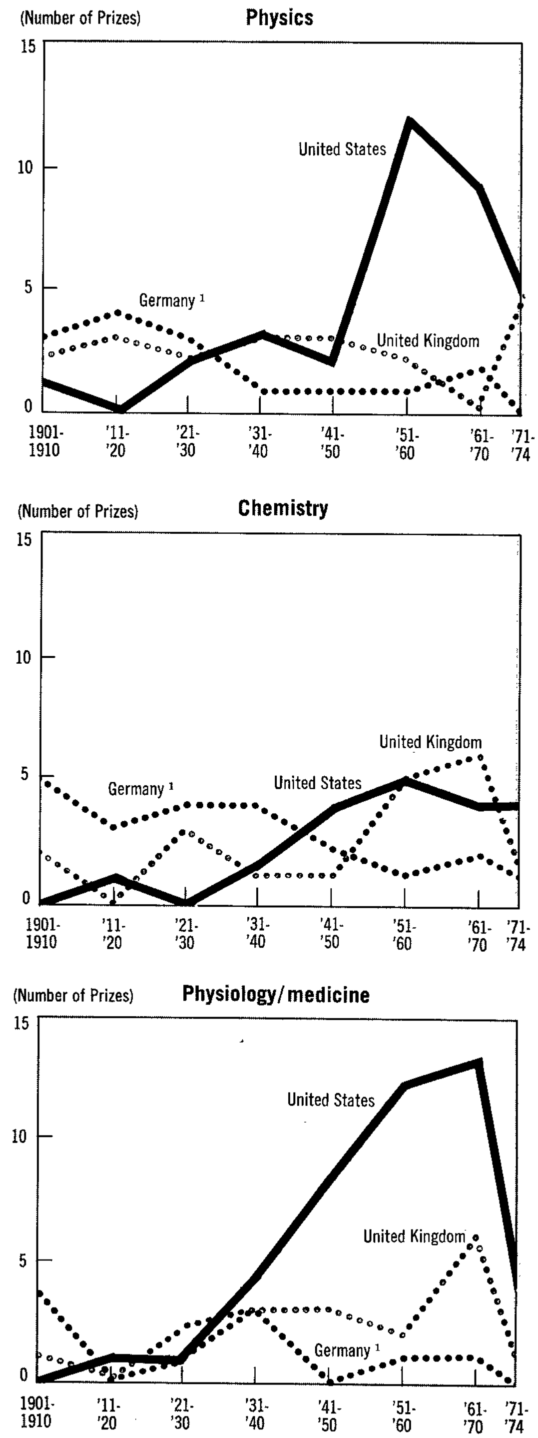
Nobel Prizes in Science per 10 Million Population for Selected Countries, 1960-1974



¹ After 1945, excludes the German Democratic Republic.
SOURCE: The Nobel Foundation.

Figure 1-9

Nobel Prizes Awarded by Field for Selected Countries, 1901-74



¹ After 1945, excludes the German Democratic Republic.
SOURCE: The Nobel Foundation.

TECHNOLOGICAL INVENTION AND INNOVATION

This section presents indicators of international trends in technological invention and innovation, as well as transactions in technology involving the United States. Indicators of inventions are based upon patent awards in the United States and abroad, and include the identification of areas of technology in which recent patenting activity by foreign countries in the United States was especially high. Innovation indicators are based on major new products of a technological nature, and include trends in the proportion of such innovations produced by each major nation, the time between invention and market introduction, and the "radicalness" of the innovations. Transactions in technology, measured in terms of international sales of technical "know-how", are used as an approximate indicator of the relative state of U.S. technology.

The "patent balance"

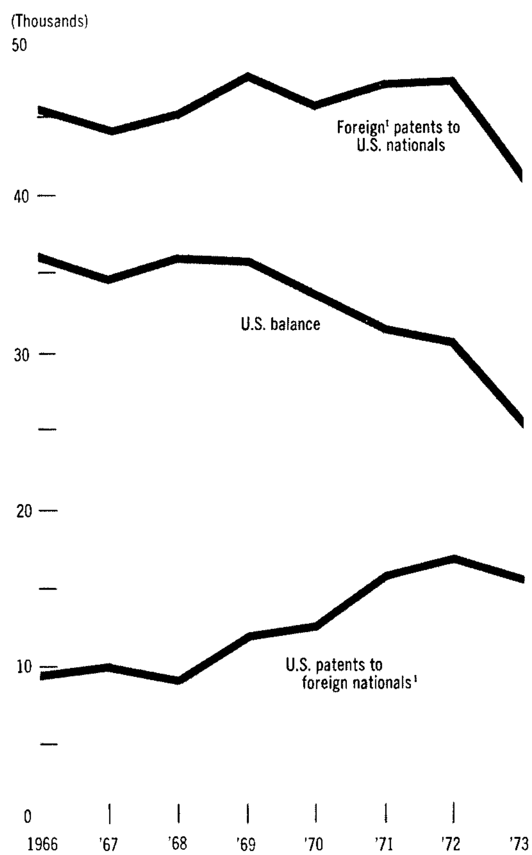
Inventions of new and improved products and processes may represent actual or potential advances in technology. Those inventions which are of sufficient originality to be patented provide a basis for indicators of the inventive output of countries. The use of patent statistics for this purpose, however, has several limitations. Some inventions—even major ones—are not patented. And those which are patented vary greatly in their technical and economic significance, with only a small proportion of the total number of inventions ultimately reaching the market. In addition, the criteria for awarding patents differ from country to country; not only does the rigor of tests for originality vary, but so does the extent of protection afforded by patents. The latter factors determine the relative ease and value of obtaining patents in different countries.

The number of patents granted in individual countries is not an adequate measure of inventiveness for purposes of international comparisons. A more meaningful measure relates the number of patents granted to nationals with those granted to foreigners in each country. Such an index[26] reflects the relative success of countries producing inventions of sufficient potential significance to warrant international patent protection. Since it is generally more costly to obtain such protection, the index tends to focus on those inventions which are thought to be most important.

Figure 1-10 presents the total number of patents granted to U.S. nationals by ten countries (Canada, West Germany, Japan, U.S.S.R., United Kingdom, and five other European Economic Community countries, including Belgium, Denmark, Ireland, Luxembourg, and the Netherlands); the number granted to nationals of these countries by the United

Figure 1-10

Patents Granted to U.S. Nationals by Foreign Countries and to Foreign Nationals by the United States, 1966-73



[1] Including Canada, West Germany, Japan, United Kingdom, U.S.S.R., Belgium, Denmark, Ireland, Luxembourg, and the Netherlands.
SOURCE: World Intellectual Property Organization.

[26] When applied to the United States, the index is the number of patents granted to U.S. nationals by foreign countries minus the number of patents granted to foreign nationals by the United States.

States; and the resulting U.S. balance. These 10 countries were responsible for nearly 70 percent of all foreign patent transactions with the United States during 1966-73. (Data are not available for Italy, and are not reliable for France for use in this report).

The "patent balance" of the United States fell by about 30 percent between 1966 and 1973, as shown in figure 1-10. The decline was due both to an increasing number of U.S. patents awarded to foreign countries and a decline (in 1973) in the number of foreign patents awarded to U.S. citizens. Overall, foreign patenting increased in the United States during the period by over 65 percent, and by 1973 represented more than 30 percent of all U.S. patents granted. This suggests that the number of patentable ideas of international merit has been growing at a greater rate in other countries than in the United States.

The United States has a favorable but declining patent balance with each country except West Germany and the U.S.S.R.[27] (figure 1-11). The favorable balance with Japan has declined steadily since 1968, as its patenting of inventions in the United States increased some threefold. The U.S.balance with Canada dropped sharply after 1972 as a result of a 30 percent reduction in the number of patents granted by Canada to U.S. inventors.

Foreign origin patents by product area. The rapid growth of foreign patenting in the United States has occurred in a broad spectrum of product areas and technologies. The number of such foreign patents granted in these areas can be used to identify the products and technologies in which the foreign impact is greatest.

For this purpose, all U.S. patents granted during 1963-73 were assigned to 15 major product areas according to the probable areas of application of the invention.[28] The percentage of foreign origin patents within each of these areas in 1973 is presented in the table below.

In 1963, the proportion of foreign origin patents in 12 of the 15 areas was less than 20 percent; only one area—petroleum refining and extraction—had less than 20 percent foreign patents in 1973.

In studies of more specific fields and technologies, the U.S. Patent Office has identified a number of areas in which the foreign share of U.S. patents is particularly high and increasing rapidly.[29] Listed below are some of these areas and the corresponding foreign share of patents during 1972:

Areas	Percent of U.S. patents to foreign countries
Piezoelectric compositions	78
Magnetic field responsive resistors	72
Automatic transmissions	69
Superconductors	60
Vinyl halide polymers	56
Ground effect machines	54
Semiconductor internal structures	52
Magnetic sound recording and reproducing structures	52
Magneto-hydrodynamic generators	49
Ignition timing controls	49

Japan, West Germany, and the United Kingdom received the greatest proportion of foreign patents awarded by the United States in these areas.

Percent of total U.S. patents granted to foreign countries by major product area, 1973

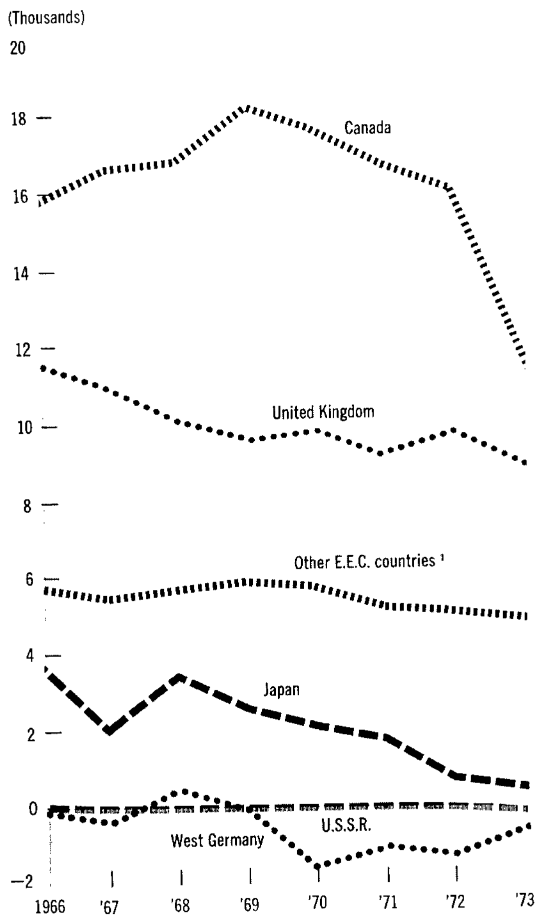
Product area	Percent	Product area	Percent	Product area	Percent
Drugs and medicines	44	Food and kindred products	33	Motor vehicles and other transportation equipment	28
Aircraft and parts	39	Machinery, except electrical	30	Rubber and miscellaneous plastics products	28
Textile mill products	37	Electrical equipment, except communications	29	Stone, clay and glass products	27
Chemicals, except drugs	35	Professional and scientific instruments	29	Fabricated metal products	25
Primary metals	34	Communication equipment and electronic components	28	Petroleum refining and extraction	17

[27] The U.S.S.R. accounted for only one percent of all the patent transactions considered.

[28] *Indicators of the Patent Output of U.S. Industry*, Office of Technology Assessment and Forecast, U.S. Patent Office, 1974 (A study commissioned specifically for this report).

[29] This information was taken from a series of reports of the Office of Technology Assessment and Forecast, U.S. Patent Office, April 1973-January 1975.

Figure 1-11
U.S. Patent Balance with Selected Countries, 1966-73



¹ Other European Economic Community (E.E.C.) countries include Belgium, Denmark, Ireland, Luxembourg, and the Netherlands. Data are not available for Italy, and are not reliable for France for use in this study.
SOURCE: World Intellectual Property Organization.

International trends in technological innovation

Technological innovation is a complex process culminating in the introduction of new and improved products and processes. Several steps are involved in bringing a new product into the market, including successful research and development which provide the technical and engineering foundation for innovation. Technological innovation is, in turn, one of the more important factors in determining the productivity, economic growth, and international position of developed nations.[30]

The indicators presented here concerning international trends in technological innovation are based upon a study conducted specifically for this report. The study investigated 500 major technological innovations (i.e., new products or processes embodying a significant technological change) which were introduced into the commercial market[31] between 1953-73. The 500 innovations studied were those receiving the highest ratings among 1,300 major innovations produced by Canada, France, Japan, the United Kingdom, the United States[32] and West Germany. An international panel of experts rated the innovations based on their technological, economic, and social importance.[33]

The present indicators should be interpreted with their several limitations in mind. The number of innovations on which the indicators are based is relatively small, particularly for countries other than the United States, with the result that the national trends presented are somewhat tenuous. Furthermore, only the most important innovations are represented by the indicators, even though the more numerous innovations of a less significant nature may have a greater overall impact. Moreover, the measures do not go beyond the initial introduction of the innovations into the market and, thus, do not include information on factors such as the economic benefits accrued by the innovating nations nor the international diffusion of the innovations. Finally, the indicators do not account for the negative impacts—such as job displacement, environmental pollution, or in-

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[30] For further discussion of these relationships see: *The Conditions for Success in Technological Innovation*, Organisation for Economic Co-operation and Development, 1971, and Robert Gilpin, *Technology, Economic Growth, and International Competitiveness*, U.S. Congress, Joint Economic Committee, 94th Congress, 2nd Session, 1975.

[31] Some innovations were brought into the commercial market after having been first introduced in the government market.

[32] The U.S. innovations are more fully analyzed in the "Industrial R&D and Innovation" chapter of this report.

[33] For further information on the methodology and results of the study see *Indicators of International Trends in Technological Innovation*, Gellman Research Associates, Inc., 1975. (A study commissioned specifically for this report). Other topics investigated in the study but not discussed here include: the characteristics of the innovating companies, the role of basic and applied research in the development of each innovation, and the utilization of patents and licensing in acquiring the technology associated with each innovation.

creased energy consumption—which may be associated with the innovations.

The innovations included in the study represent a wide range of product areas and industrial sectors. Examples of the innovations are listed below:

Nuclear reactors	Automatic optical readers
Oral contraceptives	High speed electric trains
Urethane foams	Integrated circuits
Electron beam welding	Lasers
High voltage electric cables	Weather satellites

The innovations were classified according to the type of market which the innovating company intended for the innovation[34]: producer goods, consumer goods, or the government (viewed as both a producer and a consumer market). The innovations in total were aimed principally at the producer-goods market (65 percent of all innovations), followed by the government (19 percent), and the consumer-goods market (16 percent). The following table shows the distribution of innovations among the three types of markets for each of the five countries:[35]

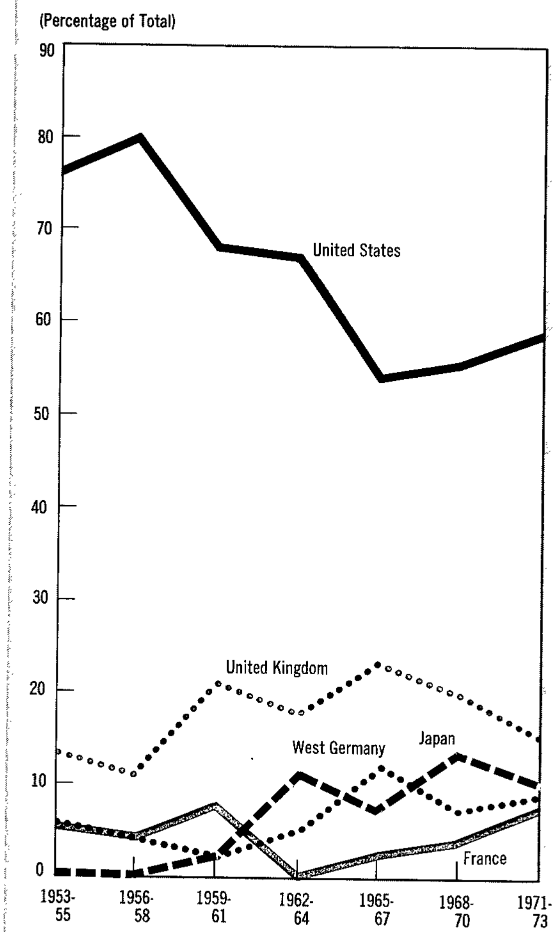
Percent distribution of innovations by type of market and country, 1953-73

Country	Type of market: Producer goods	Government	Consumer goods
United States ...	62	19	19
United Kingdom .	89	2	9
Japan	77	16	7
West Germany ..	69	7	24
France	45	10	45

Major innovations by selected countries. The proportion of the 492 innovations produced by each of the five countries is shown in figure 1-12. The United States leads each of the other nations by a wide margin in the percentage of major innovations produced. The U.S. lead, however, declined steadily from the late 1950's to the mid-1960's, falling from 82 to 55 percent of the innovations. The slight upturn in later years represents a relative rather than an absolute gain, and results primarily from a decline in the proportion of innovations produced in the United Kingdom, rather than an increase in the number of U.S. innovations. The largest actual gains were recorded by Japan, although its share of the innovations reached only some 10 percent by the early 1970's.

The innovations as a whole covered a wide range of product areas, but U.S. innovations were concentrated primarily in the most R&D-intensive industries, particularly: electrical equipment and communications, chemicals and

Figure 1-12
Major Technological Innovations, by Selected Countries, 1953-73



SOURCE: Gellman Research Associates, Inc.

[34] The innovation may have been introduced subsequently into other markets; e.g., innovations initially directed to the government may have been introduced later into another market.

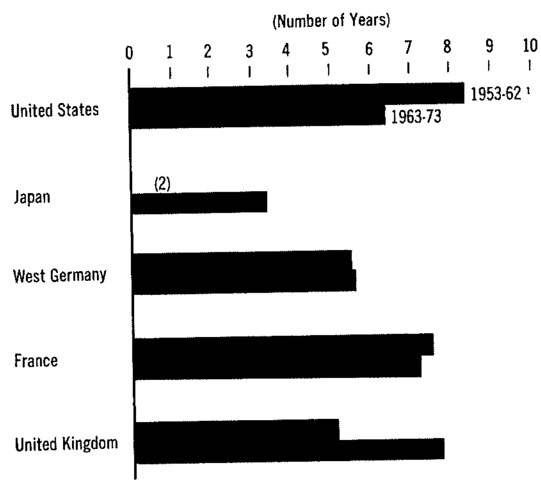
[35] Innovations originating in Canada were omitted from this report because they are small in number and therefore cannot be analyzed in detail.

allied products, machinery, and professional and scientific instruments. In the United Kingdom, aircraft was the principal area in which the innovations were found, whereas those of West Germany were primarily in machinery. Innovations originating in Japan were most often in primary metals or in the broad area of electrical equipment and communication. French innovations were least concentrated, tending to occur in a variety of areas.

Invention and innovation. The inventions (i.e., the first conception of the innovations) originate, for the most part, in the same country as the innovation; 91 percent of all the innovations included in this study were based on domestic inventions. The proportion of each country's innovations which resulted from its own inventions ranged from a high of 100 percent in France to a low of 79 percent for West Germany, with the United States at 93 percent.

The time between invention and innovation ranged from less than one year to 81 years among the present set of major new products and processes. The mean numbers of years in the invention-innovation interval are shown in figure 1-13 for the various countries. (It should be noted that the date of invention is often difficult to determine precisely).

Figure 1-13
Interval Between Invention and Innovation, for Selected Countries, 1953-73



¹ Refers to the date of the innovation.
² Sample size does not allow calculation of the time interval.
SOURCE: Gellman Research Associates, Inc.

In the most recent period, 1963-73, Japan had the shortest period between invention and market introduction (3.6 years), followed by West Germany (5.6 years), the United States (6.4 years), France (7.3 years), and the United Kingdom (7.5 years).

"Radicalness" of the innovations. Innovations may embody technologies which range from imitations of existing technologies to radical breakthroughs. To investigate this aspect, each innovation was classified by the innovating company into one of the following five categories: "no new knowledge required", "imitation of existing technology", "improvement of existing technology", "major technological advance", and "radical breakthrough". Only 22 of the 369 innovations for which such data were acquired were assigned to the first two categories; these innovations are excluded from the following analysis. The distribution of the remaining innovations among the other three categories is presented in figure 1-14.

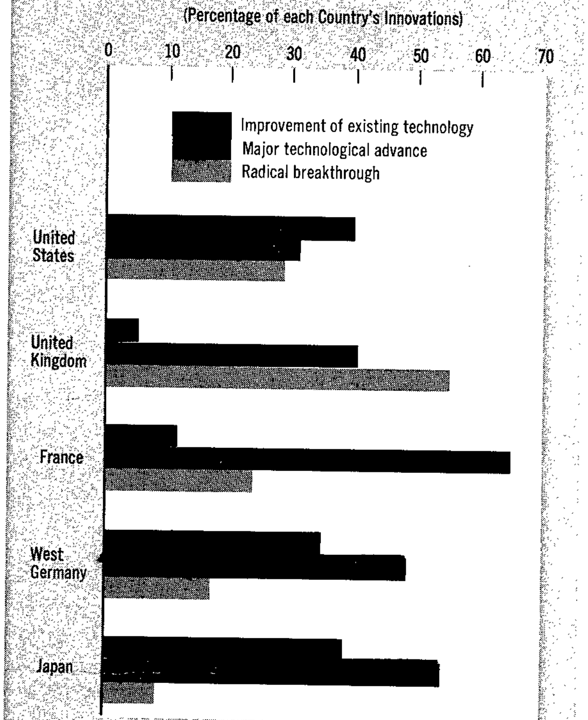
The largest proportion of innovations in the five countries combined were classified as major technological advances (37 percent), followed by improvements in existing technology (35 percent), and radical breakthroughs (29 percent). The innovations originating in the United States were a relatively balanced mix of the three types, whereas innovations of the United Kingdom were most often characterized as radical breakthroughs. France, West Germany, and Japan were similar in that their innovations were most often considered to be major technological advances.

These indicators are particularly inexact for all countries other than the United States because of the small number of innovations involved. Furthermore, only the U.S. innovations were numerous enough to permit the determination of trends, which indicate that the percentage of radical innovations declined nearly 50 percent between the 1953-59 and 1967-73 periods, while those representing major technological advances doubled. The decline in radical innovations was due to a smaller number of such innovations from the electrical equipment and communication, and the machinery industries.

Technical "know-how"

The extent to which nations purchase the technical "know-how" (e.g., patents, licenses,

Figure 1-14
"Radicalness" of Innovations, by Selected Countries, 1953-73



SOURCE: Gellman Research Associates, Inc.

and manufacturing rights) of a country is one indicator of the technological position of that country *vis-a-vis* other nations. Several other factors, however, may influence the volume of such purchases, such as the economic development policies of the nations involved and the trading arrangements among them.

Information on payments and receipts for technical "know-how" is available for transactions between multinational companies and their foreign affiliates as well as between independent organizations. The latter information was selected for use primarily on the assumption that purchases by independent enterprises are more likely to be based on the technical merit of all available "know-how". The omission of transactions between corporations and their foreign affiliates, however, results in a substantial understatement of the extent of technology transferred. In addition, a significant amount of "know-how" is transferred through the exchange of technical and management personnel, and through informal agreements which are not reflected in the financial data presented here.

The dollar value of U.S. receipts, payments, and the resulting balance (i.e., receipts minus payments) for exchange of technical "know-how" is shown in figure 1-15. Over the 1960-74 period, U.S. receipts from the sale of "know-how" grew exponentially while its payments grew more linearly, resulting in an increasingly large positive balance of payments in this area. Increases in the U.S. balance are due principally to purchases of U.S. "know-how" by Western Europe and Japan (accompanied by relatively small purchases of Japanese "know-how" by the U.S.). From 1970 onward, for example, nearly 45 percent of U.S. net receipts were associated with Japan, and 30 percent with Western Europe (including the United Kingdom). The developing countries are increasingly important purchasers of U.S. "know-how", accounting for 15 percent of the U.S. balance in 1974.

U.S. purchases of foreign "know-how" are primarily from Western Europe. Approximately 80 percent of U.S. payments in 1974 went to these countries, with nearly 35 percent going to the United Kingdom alone.

Although considerably more technical "know-how" appears to flow from the United States than to it, the volume of foreign technology acquired by the United States is substantial and expanding in various areas. Machine tools is one such area in which the advanced "know-how" of foreign countries has been acquired for use in the United States. In plastics, the European developments in polyethylene have impacted significantly on American industry. Imported technology and "know-how" have also had substantial influence in the optical equipment area.[36]

PRODUCTIVITY AND BALANCE OF TRADE

This section presents indicators of international trends in productivity, as well as measures of the contribution of R&D to the U.S. balance of trade. Trends in the level of national

[36] *International Economic Report of the President,* Council on International Economic Policy, 1975.

Figure 1-15a

U.S. Receipts and Payments for Patents, Manufacturing Rights, Licenses, Etc., 1960-74

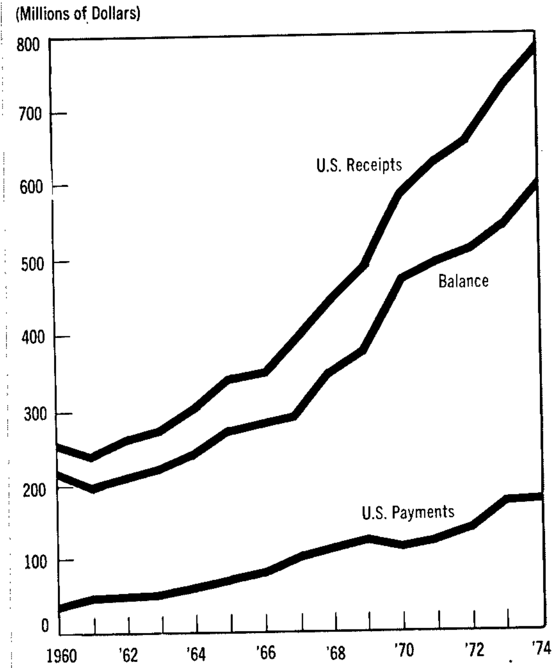
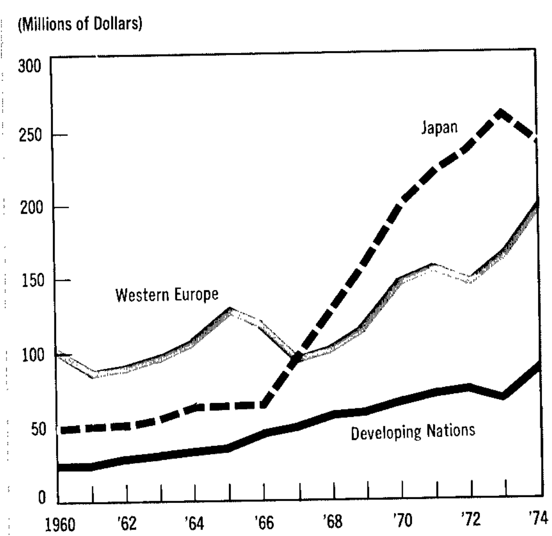


Figure 1-15b

U.S. Net Receipts for Patents, Manufacturing Rights, Licenses, Etc., by Selected Countries, 1960-74



SOURCE: U.S. Department of Commerce.

productivity (i.e., Gross Domestic Product per employed civilian) and growth in manufacturing productivity (i.e., output per man-hour) are presented for each major developed country. An approximate indicator of the role of R&D in the U.S. trade balance is developed through an analysis of U.S. exports and imports of manufactured products, in terms of the R&D intensity of the products involved. The indicator is used also to determine the balance of trade in R&D-intensive products between the United States and other specific nations.

Productivity

The level of productivity and its rate of growth can greatly influence the economic strength of nations and affect living standards, costs and prices, and international trading and monetary arrangements—as shown by the experience of many countries in recent years.[37] Productivity expresses the relationship between the quantity of goods and services produced (output) and the quantity of labor, capital, land, energy, and other resources (input) used to produce them. Over time, productivity tends to grow as new knowledge and new technology are embodied in capital investments, as the educational levels of labor forces rise, and as management skills become more effective. While the effect of R&D on productivity growth is not known precisely, the general conclusion based on a large number of studies is that the impact of R&D is "positive, significant, and high".[38]

The measurement of productivity is difficult, particularly when measures are sought for the purpose of international comparisons. Problems arise from a diversity of sources, such as differences in concept and methodology and the availability of data. For these reasons, small reported differences in productivity—between nations and over short periods—may not be significant; interpretation of the indicators, therefore, should be confined to general trends.

A relatively general and approximate measure of productivity is the "real Gross Domestic

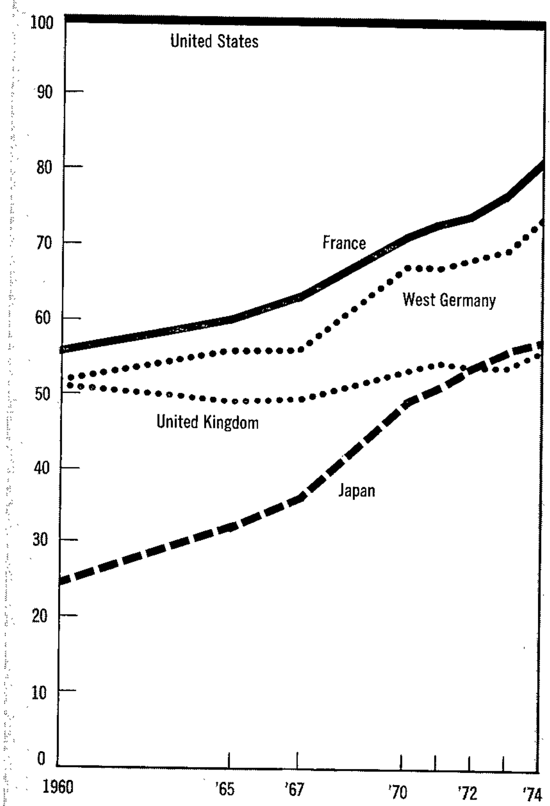
[37] Information on the role of productivity in the international area may be found in *Productivity: An International Perspective*, U.S. Department of Labor, Bureau of Labor Statistics, 1974.

[38] *Research and Development and Economic Growth/Productivity*, Papers and Proceedings of a colloquium, National Science Foundation (NSF 72-303). For a discussion of this relationship, see the chapter entitled, "Industrial R&D and Innovation" in this report.

Figure 1-16

Real Gross Domestic Product per Employed Civilian, for Selected Countries Compared with the United States, 1960-74

(Indexes, United States = 100)



SOURCE: U.S. Department of Labor.

Product per employed civilian". Measured in these terms, the level of U.S. productivity exceeded that of France, Japan, West Germany, and the United Kingdom throughout the 1960-74 period (figure 1-16). Gains in productivity, however, were larger in the four other countries, with the result that the U.S. lead diminished significantly. By 1974, the productivity levels of France and West Germany were only 20-25 percent lower than the United States. Japan gained the most in productivity, but was still some 40-45 percent below the U.S. level in 1974.

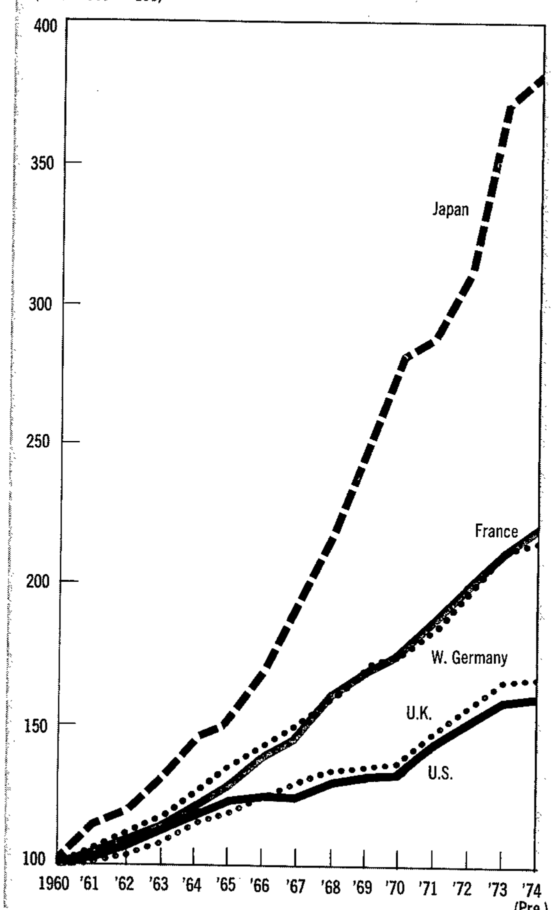
Trends in productivity are more commonly measured in terms of output per man-hour. The use of this index does not imply that labor alone is responsible for productivity growth; output per man-hour may also be influenced by factors such as technological advances, scale of production, and management effectiveness. This index is developed for each country separately, and is used to measure the change in productivity over time in that country; it does not permit comparisons of the actual productivity levels of different countries.

This indicator is presented in figure 1-17 for manufacturing industries in the five countries. The U.S. productivity gain between 1960-74 is the smallest of these five countries (60 percent)

Figure 1-17

Productivity[1] in Manufacturing Industries, by Selected Countries, 1960-74

(Index 1960 = 100)



[1] Output per man-hour.

SOURCE: U.S. Department of Labor.

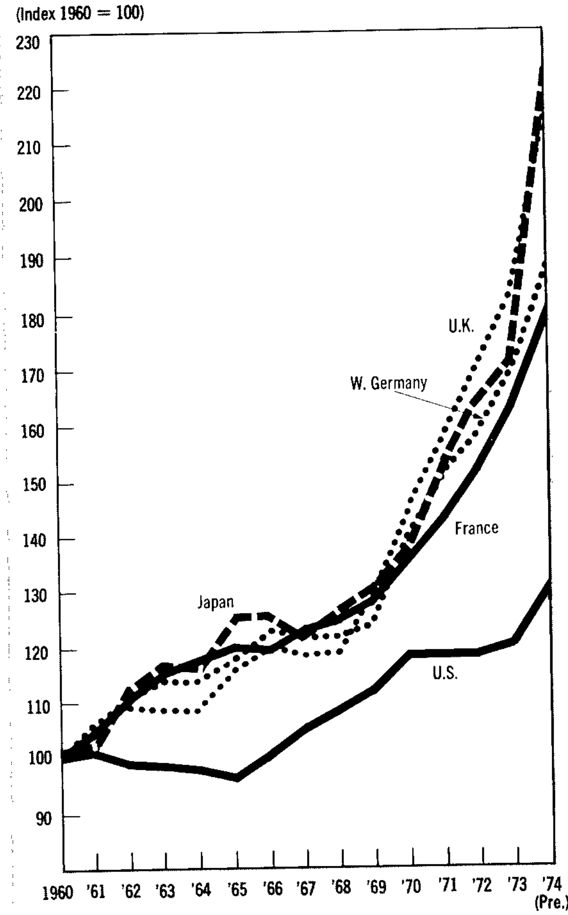
and nearly five times less than increases in Japan, which recorded the largest gains. However, starting from a relatively high level of productivity in 1960, the United States might not be expected to sustain the same high proportional gains as countries starting from a lower productivity base.

The effectiveness of a nation's productivity level is perhaps best indicated by the measure of "unit labor cost" (i.e., hourly labor costs divided by output per man-hour). If gains in productivity exceed increases in the cost of labor, then unit labor costs drop, products can be produced at less cost, and sold at lower prices, placing a nation in a favorable competitive position in the international market.[39]

Trends in this index for manufacturing industries are shown for the five countries in figure 1-18. It can be seen that productivity gains in the U.S. were sufficient to offset increases in labor cost from 1960 through 1965 and again from 1970 through 1973. Productivity rises in 1974 were negligible, however, while hourly labor costs had the largest yearly gain of the entire period. As a result, unit labor costs in manufacturing industries rose more rapidly than in any other year since World War II.

Gains in hourly compensation in 1974 exceeded advances in productivity in other countries also, and by even wider margins than in the United States. Thus, unit labor costs increased to an even greater extent in foreign manufacturing. The 1973-74 increase in Japan was nearly 30 percent and in the United Kingdom nearly 20 percent, both of which were the largest year-to-year gains in unit labor costs experienced by these countries during the 1960-74 period.

Figure 1-18
Unit labor cost[1] in Manufacturing Industries, by Selected Countries, 1960-74



[1] In national currency unadjusted for inflation.
SOURCE: U.S. Department of Labor.

Balance of trade in R&D-intensive products

The U.S. position in world trade depends upon a variety of factors, including the price of its products, the effectiveness of its international marketing, trading arrangements with other countries, and its performance in technological innovation. Such innovation, as discussed elsewhere in this report, depends significantly upon research and development.

The precise role of R&D and technological innovation in U.S. trade have not been determined, although recent studies suggest that it is substantial.[40] Some indication of this is provided by analyzing the U.S. trade balance in terms of the products involved, with the latter classified according to the relative level of R&D investment of the industries which produce the products. For this purpose, products from industries[41] with (a) 25 or more scientists and

[39] For a discussion of recent trends in these factors, see Patricia Capdevielle and Arthur Neef, "Productivity and Unit Labor Costs in the United States and Abroad", *Monthly Labor Review*, July 1975; for a detailed analysis of the role of these factors in international trade, see *Competitiveness of U.S. Industries*, United States Tariff Commission, 1972.

[40] Raymond Vernon (ed.), *The Technology Factor in International Trade*, (New York: Columbia University Press, 1970).

[41] Only manufacturing industries (which account for nearly all industrial expenditures for R&D) are included in the analysis.

engineers engaged in R&D per 1,000 employees and (b) company-funded R&D amounting to at least 3 percent of their net sales, were regarded as "R&D-intensive" products.[42] Based on these criteria, the product areas identified as R&D-intensive are (1) chemicals, (2) nonelectrical machinery, (3) electrical machinery, (4) aircraft and parts, and (5) professional and scientific instruments. All other manufactured products were regarded as non-R&D-intensive.

The U.S. trade balance (exports minus imports) associated with these two categories of products is shown in figure 1-19.[43] The favorable balance in R&D-intensive products is clearly indicated; the balance increased fourfold over the 1960-74 period and doubled between 1970-74 alone. In contrast, the United States had a large and increasing trade deficit in non-R&D-intensive products. The principal products in this area which accounted for the deficit were motor vehicles, textiles, and metals.[44]

The favorable U.S. trade balance in products from R&D-intensive industries is shown in figure 1-20.

Nonelectrical machinery accounted for nearly one-half of the favorable balance in R&D-intensive products. The recent growth in the balance for this area was largely the result of increased export of electronic computers, construction equipment, and mining and well-drilling machinery.

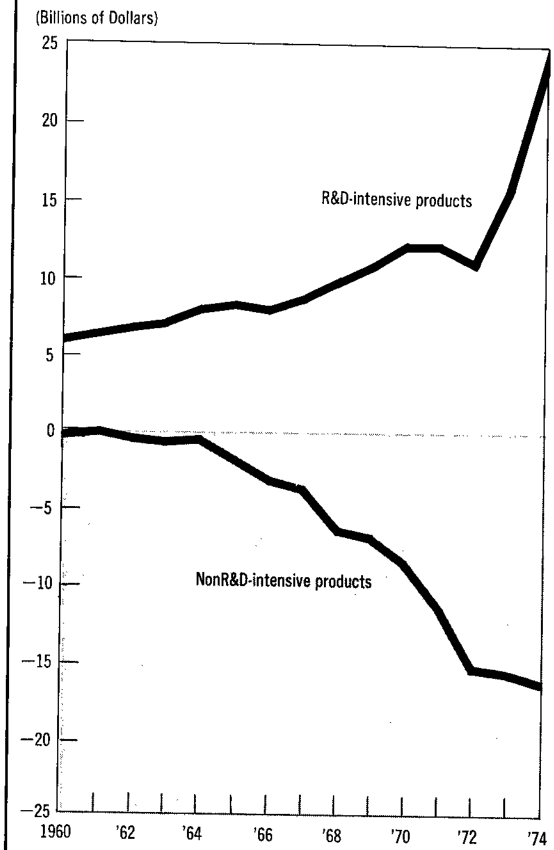
Aircraft and parts contributed approximately one-fifth of the positive balance in R&D-intensive products in 1974. This is the only one of the five areas in which imports decreased between 1973 and 1974.

Chemicals accounted for an additional one-fifth of the positive balance in R&D-intensive products. The recent increase in net exports of chemicals was due largely to growth in the exports of plastics, medicinal and pharmaceutical products, and manufactured fertilizers.

Electrical machinery had the smallest margin of exports over imports, as a result of large and increasing imports in telecommunications apparatus, without comparable increases in exports of other types of electrical machinery.

Figure 1-19

U.S. Trade Balance in R&D-intensive and NonR&D-intensive Manufactured Products, 1960-74



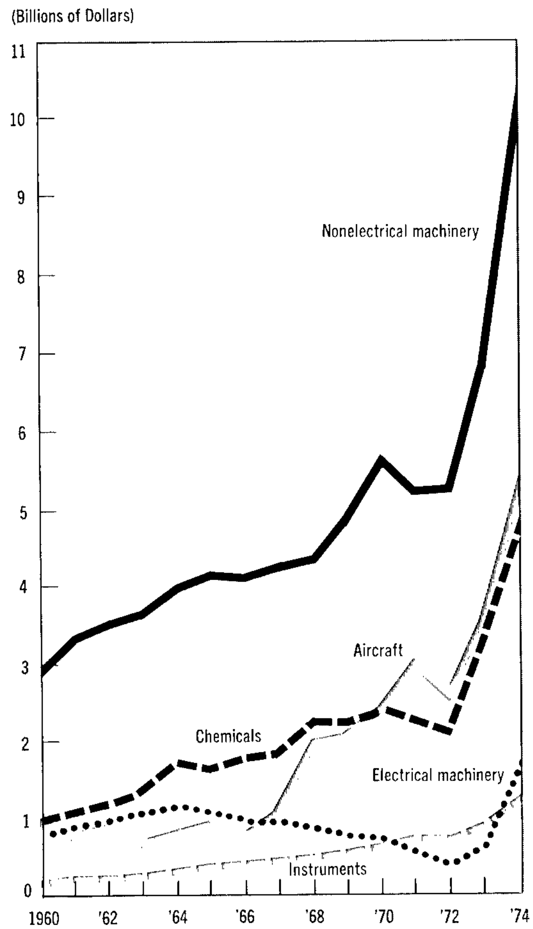
SOURCE: U.S. Department of Commerce.

[42] This grouping, of course, is an approximate one. Products and industries, although highly correlated at the gross level, do not perfectly coincide, with the result that not all products manufactured by a high R&D-performing industry can be considered R&D-intensive.

[43] The export statistics presented here include all merchandise shipped from the U.S. customs area, with the exception of supplies destined for U.S. Armed Forces abroad for their own use; shipments for relief purposes or under military assistance programs are included. The import statistics cover foreign merchandise received in the U.S. customs area.

[44] The trends in U.S. foreign trade presented here were influenced by recent adjustments in the international monetary system. In December 1971, the United States reduced the par value of the dollar; in March 1974, all of the major world currencies converted to a system of floating exchange rates. The precise impact of these changes on the U.S. trade position is not known, but in general they are thought to enhance the competitiveness of U.S. exports. A detailed discussion of this topic is presented in the *Economic Report of the President*, Council of Economic Advisers, 1975.

Figure 1-20
U.S. Trade Balance in R&D-intensive Manufactured Products, by Product Group, 1960-74



SOURCE: U.S. Department of Commerce.

Professional and scientific instruments maintained a steady but small growth in net exports through 1974.

There have been substantial changes over the last decade in the mix of products underlying the favorable trade balance. Several products have become increasingly important to the maintenance of the positive trade balance in R&D-intensive products (including electronic computers, fertilizers, electronic tubes, transistors and semiconductor devices), while the contribution of other commodities (such as telecommunications apparatus) has led to a negative balance. This mixture of growing and declining exports illustrates the complexities of the present U.S. trade position. The underlying dynamics of the position, however, are partially explained by the "product cycle" concept.[45] Trade in manufactured goods, according to this concept, typically follows a cycle in which the United States initially establishes a net export position with the introduction of a new product, maintains this position until the technologies and skills necessary for manufacturing the product are developed elsewhere, and then becomes an importer as the production is standardized and moves abroad to minimize costs. This concept implies that the product structure of U.S. exports must have a continuous infusion of new products in order for the United States to maintain a favorable trade position.

The favorable position of the United States in R&D-intensive products is based primarily on exports to developing nations, countries of Western Europe, and Canada.[46] The U.S. trade balance in these products is shown in figure 1-21 for selected areas and countries. In 1973, the developing nations accounted for 44 percent of the positive U.S. trade balance; nonelectrical machinery and chemicals were particularly large net export commodities for the United States in trade with these nations. In the case of trade with Western Europe, the United States had its largest net exports in the areas of aircraft and nonelectrical machinery (particularly in computers). U.S. net exports to Canada are concentrated in the areas of nonelectrical and electrical machinery.

A trade deficit in R&D-intensive products developed with Japan in the mid-1960's and persisted through 1974. This deficit occurred primarily in electrical machinery products (particularly consumer electronics) and to a lesser degree in professional and scientific instruments and nonelectrical machinery. Only in the areas of chemicals and aircraft does the

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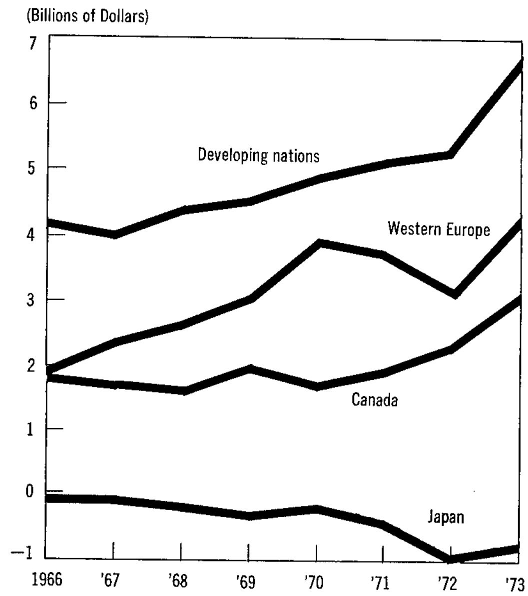
[45] Raymond Vernon, "International Investment and International Trade in the Product Cycle", *Quarterly Journal of Economics*, Vol. 80, May 1966.

[46] For a more complete discussion of these relationships see Keith Pavitt, " 'International' Technology and the U.S. Economy: Is there a Problem?" in *The Effects of International Technology Transfers on U.S. Economy*, National Science Foundation, Papers and Proceedings of a Colloquium (NSF 74-21).

Figure 1-21

U.S. Trade Balance with Selected Nations in R&D-intensive Manufactured Products, 1966-73



SOURCE: U.S. Department of Commerce.

United States have a significant net export position with respect to Japan. (It might be noted that the United States also has a negative trade balance with Japan in non-R&D-intensive products).

The importance of the positive trade balance in R&D-intensive products is illustrated by the fact that the net exports of such products in 1974 ($23.6 billion) were large enough to offset the negative balance in petroleum products ($23.4 billion) for that same year.[47]

Agriculture is an additional component of foreign trade which is significantly affected by the position of U.S. technology. The leading role of U.S. agriculture is due at least in part to the contributions of science and technology in such areas as the development of new hybrids; the utilization of irrigation techniques; the improvement of fertilizers, pesticides, and herbicides; and the widespread mechanization of production.[48] In 1974, the United States exported $22.3 billion of agricultural commodities (with especially high volume in wheat, soybeans, and corn), and had a positive trade balance of $11.9 billion in agricultural commodities as a whole.[47]

The preceding examination of foreign trade was restricted, for the purposes of this report, to those aspects which provide relatively direct indices of the position and performance of U.S. technology. As a result, such topics as foreign direct investment, sales of U.S. subsidiaries abroad, and the impact of multinational corporations were not discussed.[49]

[47] *Overseas Business Reports,* Department of Commerce, Domestic and International Business Administration (OBR 75-22).

[48] *Agricultural Production Efficiency,* National Academy of Sciences, Washington, D.C., 1975.

[49] For further treatment of these topics see the *International Economic Report of the President,* Council on International Economic Policy, 1975.

Resources for Research and Development

Resources for Research and Development

INDICATOR HIGHLIGHTS

- National expenditures for research and development (R&D) in the United States increased in current dollars each year between 1960-74, reaching $32 billion in 1974; in constant dollars, however, expenditures remained at $22-23 billion between 1968 and 1974.
- The total number of (full-time equivalent) scientists and engineers engaged in R&D reached its highest level in 1969 (at 558,000) and declined to almost 528,000 in 1974; the decline is due largely to reductions of such personnel in industry as a result of cutbacks in Federal funds in the aerospace area.
- The fraction of the gross national product (GNP) going to R&D declined steadily from a high of nearly 3.0 percent in 1964 to a low of 2.3 percent in 1974; Federal funds for R&D, as a fraction of GNP, dropped from 2.0 to 1.2 percent between 1964 and 1974, whereas funds from all other sources combined remained at approximately 1.0 percent of GNP throughout the period.
- Federal funds for R&D increased in current dollars in all but two of the years between 1960-74, reaching their highest level of nearly $17 billion in 1974; funding in constant dollars, however, peaked in 1966 and was down by 19 percent in 1974 to less than $12 billion, which is equivalent to the funding level of 1963.
- R&D funds provided by industry rose more rapidly than those of the Federal Government during the 1960-74 period, reaching nearly $14 billion in current dollars in 1974; funds in constant dollars were at their highest level in 1973, some 2 percent above the level of 1974.
- The Federal Government and industry provided 96 percent of all the funds for R&D in 1974; the Federal share of the total declined from a high of 65 percent in 1965 to a low of 53 percent in 1974, while industry's share grew from 33 to 43 percent of the total.
- R&D expenditures increased in current dollars in all R&D-performing sectors[1] in recent years, whereas funds expended in constant dollars were lower in each sector in 1974 than in previous years; the largest constant dollar decline was in industry where expenditures in 1974 were 9 percent lower than in 1969, due largely to declines in Federal support for industrial R&D.
- The proportion of R&D funds allocated to different types of R&D activities—basic research, applied research, and development—has remained nearly constant since 1965, with development receiving 64 percent, applied research 23 percent, and basic research 13 percent.
- R&D funds provided by the Federal Government are a declining fraction of the total Federal budget, falling from a high of 13 percent in 1965 to 7 percent in 1974; as a fraction of the "relatively controllable" portion of the Federal budget,[2] R&D spending has changed little, at 15 percent in 1974 compared with a high of 16 percent in 1967 and a low of 14 percent in 1970.
- Federal funds for R&D go primarily to national defense, with "civilian"[3] areas and space exploration receiving the remainder; the proportion of total Federal R&D funds

[1] The sectors included are industry, Federal intramural laboratories, universities and colleges with their Federally Funded Research and Development Centers, and other nonprofit institutions.

[2] That part of the budget which is subject to annual appropriations, rather than determined by fixed costs and "open ended" programs whose funds increase by law.

[3] Includes areas such as health, energy, and the environment; see figure 2-10 for a listing of the areas.

for defense remained at slightly more than 50 percent throughout 1969-74, whereas the fraction for civilian areas rose steadily from 24 to 34 percent while the share for space R&D declined from 24 to 14 percent.

- Funds from the Federal Government for civilian R&D increased 70 percent in current dollars and 28 percent in constant dollars between 1969 and 1974; the civilian fields accounting for most of the growth were health (39 percent of the total growth) and the environment (17 percent).
- Federal funds for civilian R&D are concentrated on research (applied and basic) rather than development—in contrast to defense and space R&D; in 1974, 72 percent of the funds went for research, with 45 percent going for applied research and 27 percent for basic research.
- Federal funds for laboratory equipment provided through research grants declined as a fraction of total grant funds, decreasing from 11 percent in 1966 to 5 percent in 1974.[4]
- Federal support for major fixed equipment and R&D facilities in 1974 was well below the years of highest funding in the mid-1960's even though such support has increased considerably since 1972.
- Expenditures by the Federal Government for the dissemination of the results of R&D increased in current dollars each year from 1960 through 1974, but changed little in constant dollars after 1968; the ratio of these obligations to total Federal obligations for R&D has remained at approximately .025 since 1970.

Substantial resources are committed to research and development in the United States. The largest fraction of these resources goes for R&D in a broad spectrum of national concerns, such as national defense, space exploration, health, energy, and the environment. A large and nearly comparable portion of the R&D resources is used to develop new and improved industrial products and processes. A small part of the resources is allocated for basic research to advance the understanding of nature.

"Research and development" in this report comprises basic and applied research and development activities. "Basic research" has the purpose of acquiring scientific knowledge of natural phenomena, where the primary aim is fuller understanding of the subject of study, rather than specific application of the resulting knowledge. "Applied research" has a similar although often less general purpose, but where the prime aim is the potential application of the acquired knowledge. The scientific fields encompassed in basic and applied research consist of the life sciences (including the medical sciences), physical sciences, mathematical sciences, and engineering, as well as the psychological and social sciences.[5] "Development" consists of the use of knowledge gained from research, in conjunction with technical "know-how", for the design and prototype construction of materials, devices, processes, products, systems, and methods.

Indicators presented in this chapter are intended to portray general trends in the allocation and use of financial and human resources in the Nation's overall R&D effort. These include several measures of the absolute and relative magnitude of these resources, as well as the sectors which supply and utilize them. Indicators are provided also of the financial resources which are directed to basic research, to applied research, and to development. In addition, trends in Federal funds for R&D are presented in relationship to the total Federal budget and in respect to broad areas of R&D activity. The chapter also contains indicators of the resources for research equipment and facilities, and trends in the Federal support of efforts to disseminate the results of R&D. More detailed examination of particular areas of R&D activity, and measures of output, are presented in subsequent chapters.

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[4] Based upon research grants of the National Science Foundation and the major National Institutes of Health.

[5] Data are not available on industry resources for research in the psychological and social sciences.

In this and subsequent chapters, data on R&D funding are presented in both current and constant 1967 dollars. The use of constant dollars is an attempt to reflect the reduction in the purchasing power of R&D resources which is caused by inflation, thereby providing a more accurate indication of the "real" level or magnitude of R&D funding and effort. Inflation in the economy at large has reduced the purchase value of the 1967 dollar to 69 cents in 1974, with the largest reductions occurring in the most recent years. In the absence of a price deflator specifically for R&D, the calendar year implicit price deflator for the gross national product (GNP) is used to convert current dollars to constant dollars; 1967 is chosen as the base or reference year, in keeping with Federal statistical standards. The GNP implicit price deflator, which applies to the economy as a whole, is necessarily general in scope and is only approximately appropriate for use in connection with R&D as a whole, or with specific R&D-performing sectors, types of costs, and fields of research. It is believed, however, that a uniform, though approximate, conversion method is preferable to various intuitive estimates of the effects of inflation on R&D.

The present indicators fall short of providing comprehensive and in-depth measures of trends in the allocation and use of resources for R&D. These shortcomings reflect both conceptual problems and data limitations. The indicators presented in this report do not include the full costs of R&D, and thus the magnitude of the R&D activity resulting from the investment of resources cannot be determined. The indicators, in addition, do not provide measures of the extent to which the resources engage the Nation's full R&D capacity. Furthermore, indicators have not been developed for gauging the general effectiveness with which the R&D resources are utilized, nor the efficiency with which these resources are translated into R&D activity. Another deficiency is the lack of indices of the quality of the resources which are directed to R&D, particularly the qualifications of the scientists and engineers involved and the adequacy of their research equipment and facilities. And finally, data and information are incomplete regarding the national purposes to which total R&D resources are directed; only in the case of Federal funding are R&D resources classified according to areas of national concern such as health, energy, and national defense.

NATIONAL RESOURCES FOR RESEARCH AND DEVELOPMENT

Trends in total national expenditures for research and development indicate an increasingly strong commitment from available funding resources; however the impact has been reduced by declining purchasing power due to inflation. Total expenditures in current dollars rose steadily from 1960-74 to $32 billion, almost two and one half times that for 1960 (figure 2-1). R&D funding, however, slowed concurrently with acceleration in inflation. As a result, 1968 was the peak year of total expenditures in constant dollars. Funding since then has been at a lower level; in 1974 the constant dollar total was $22.9 billion, 7 percent below the total for 1968.

The numbers of scientists and engineers employed in R&D rose and fell in close parallel with levels of constant dollar expenditures (figure 2-2), reaching a high of 558,000 in 1969. The subsequent decline occurred largely in the industry sector, as a result of reductions in Federal funding in defense and space programs.

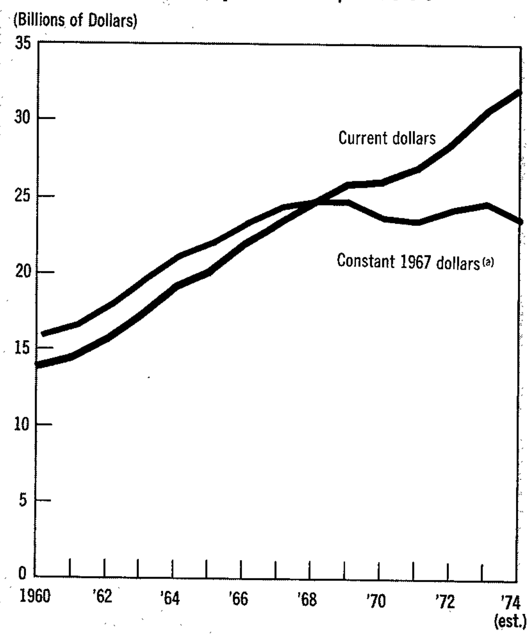
The share of the Gross National Product represented by R&D has dropped continuously over the last 10 years (figure 2-3). From a high of 2.99 percent in 1964, it declined to 2.29 in 1974. R&D funds from the private sector, particularly industry, kept pace with the GNP throughout the 1960-74 period. The growth of Federal R&D funding, however, fell behind, and as a percentage of the GNP declined from 1.99 percent in 1964 to 1.22 percent in 1974.

Sources of support

The Federal Government has been the principal source of R&D funds throughout the 1960-74 period, although the proportion of its support within total R&D funding has declined. Federal support of R&D in 1974 in current dollars was almost double its 1960 support and 18 percent higher in constant dollars (figure 2-4). The peak year for Federal support of R&D in constant dollars was 1966, followed by a 19 percent decline by 1974. Industry-supported R&D expenditures, which together with Federal support accounted for 96 percent of total national R&D expenditures in 1974, were at their highest level in current dollars in 1974, and had diminished only slightly from the 1973 peak year in constant dollars.

Figure 2-1

National R&D Expenditures, 1960-74

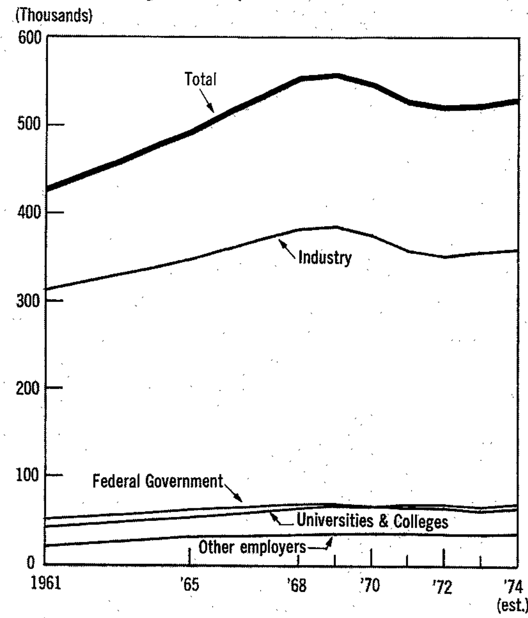


(a) GNP implicit price deflators used to convert current dollars to constant 1967 dollars.

SOURCE: National Science Foundation.

Figure 2-2

Scientists and Engineers[a] Employed in R&D by Sector, 1961-74

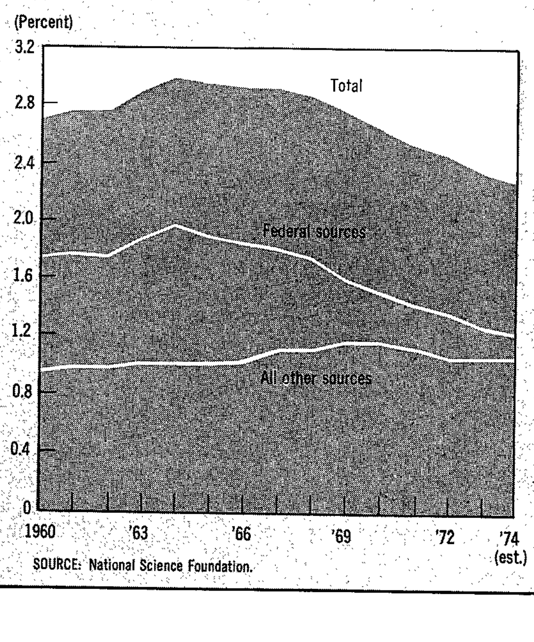


(a) Full-time-equivalent basis, excluding those employed in state and local agencies, calculated as the yearly average.

SOURCE: National Science Foundation.

Figure 2-3

National R&D Expenditures as a Percent of GNP, by Source, 1960-74



SOURCE: National Science Foundation.

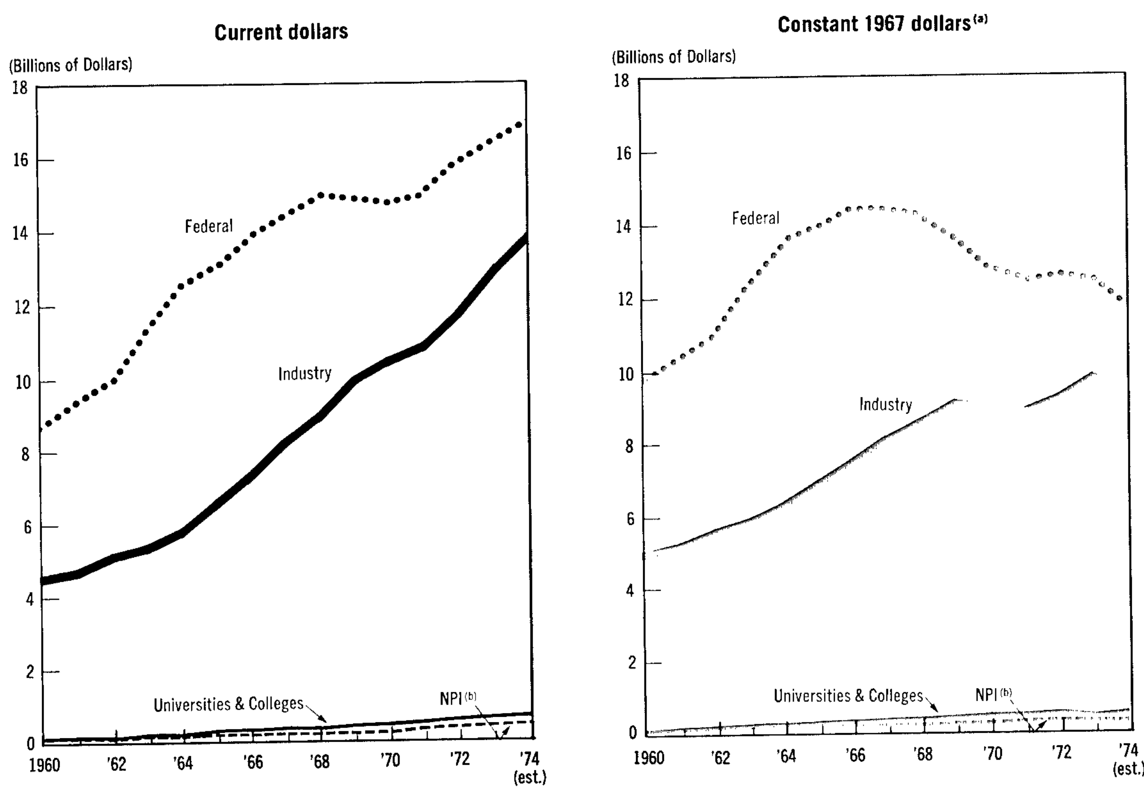
The share of total support of R&D expenditures borne by the Federal Government stood at 53 percent in 1974 (figure 2-4) compared with 65 percent in 1965. The industry proportion increased from 33 percent in 1965 to 43 percent in 1974. The combined share contributed by universities, colleges, and other nonprofit institutions has ranged between 2 and 4 percent from 1960 to 1974.

Even though the universities and colleges represent a small source of R&D expenditures, their contribution increased considerably during the period, rising from $168 million in constant dollars in 1960 to a high of $472 million in 1974.[6] This reflects, in part, the increased support provided to public institutions by state and local governments.

Other nonprofit institutions increased their spending also, growing from $160 million in constant dollar expenditures in 1960 to a high of $359 million in 1973.

[6] Data in this report for universities and colleges include only separately-organized R&D; expenditures for the usual teaching/research assignments of the faculty are excluded.

Figure 2-4
National Expenditures for R&D, by Source, 1960-74



(a) GNP implicit price deflators used to convert current dollars to constant 1967 dollars.
(b) Nonprofit institutions.
SOURCE: National Science Foundation.

Expenditures by R&D-performing sectors

R&D expenditures have increased in all performing sectors without significant interruption from 1960 to 1974 (figure 2-5). However, in all sectors the constant dollar expenditures for 1974 were less than a peak year earlier in the period. The largest decline in constant dollars has been in industry where R&D expenditures in 1974 were 9 percent lower than in 1969, the year of peak spending, and comparable to the 1965-66 level.

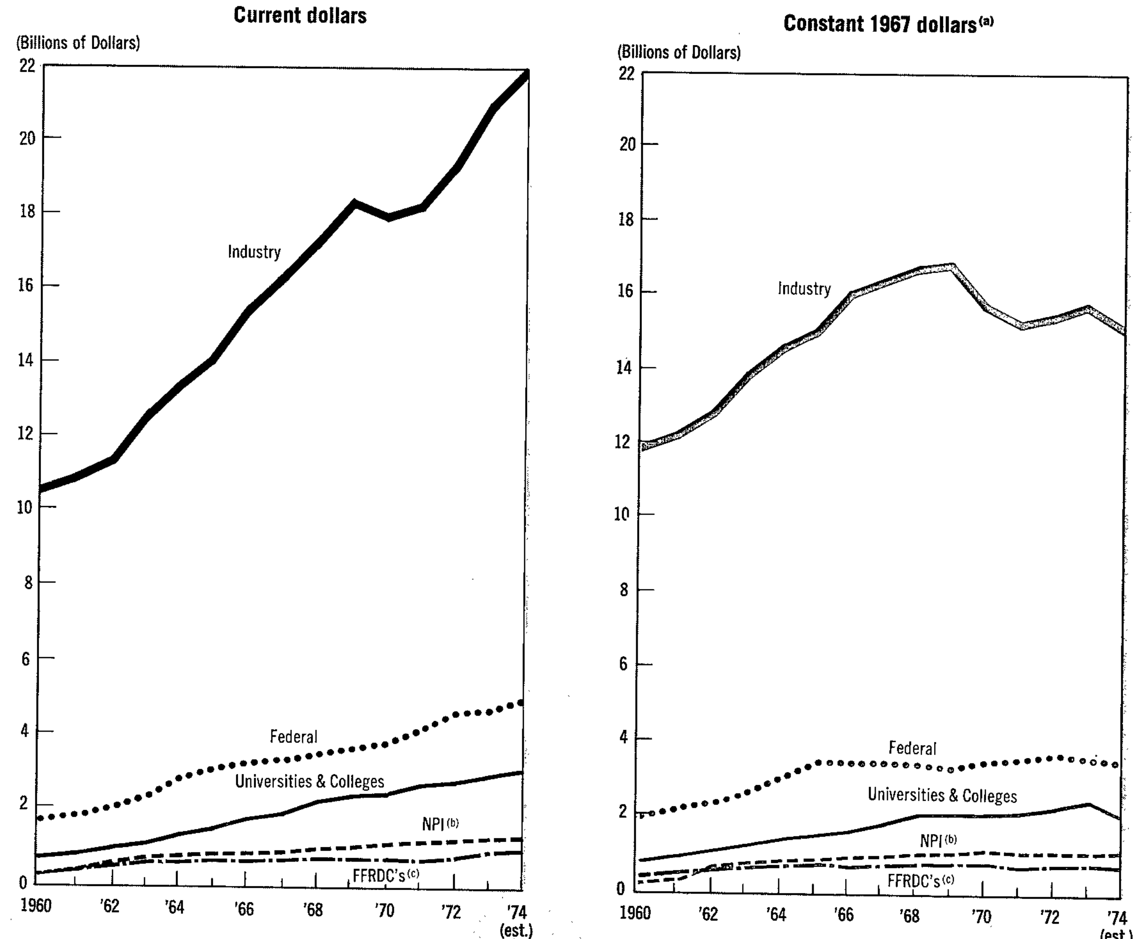
Some changes have occurred within the national R&D total in the proportions accounted for by the four sectors. Industry's share, the largest, decreased from 78 percent in 1960 to 69 percent in 1974, even while total R&D spending by industry increased. The Federal intramural laboratories expended 15 percent of the total for 1974 compared to 13 percent in 1960. The university and college portion rose from 5 to 10 percent from 1960 to 1974, while their associated Federally Funded Research and Development Centers remained at about 2 percent.

Scientists and engineers in R&D-performing sectors

The number of scientists and engineers employed in R&D was lower in each sector in 1974 than in some previous year (figure 2-2). In general, the late 1960's were the years of highest R&D employment, corresponding to the years in which R&D funding in constant dollars was at its highest levels. Declines in subsequent years were largest in industry, where the number of scientists and engineers engaged in R&D in 1974

Figure 2-5

National Expenditures for R&D, by Performer, 1960-74



(a) GNP implicit price deflators used to convert current dollars to constant 1967 dollars.
(b) Nonprofit institutions.
(c) Federally Funded Research and Development Centers administered by universities.
SOURCE: National Science Foundation.

was 26,000 fewer than in 1968. This sector, as well as Federal laboratories and universities and colleges, had a small increase in the number of R&D scientists and engineers between 1973 and 1974.

The distribution of R&D scientists and engineers[7] among performing sectors has remained nearly the same for many years (figure 2-3). Over two-thirds are employed in industry, while the Federal government and academic shares are nearly equal to one another—approximately 12-13 percent each.

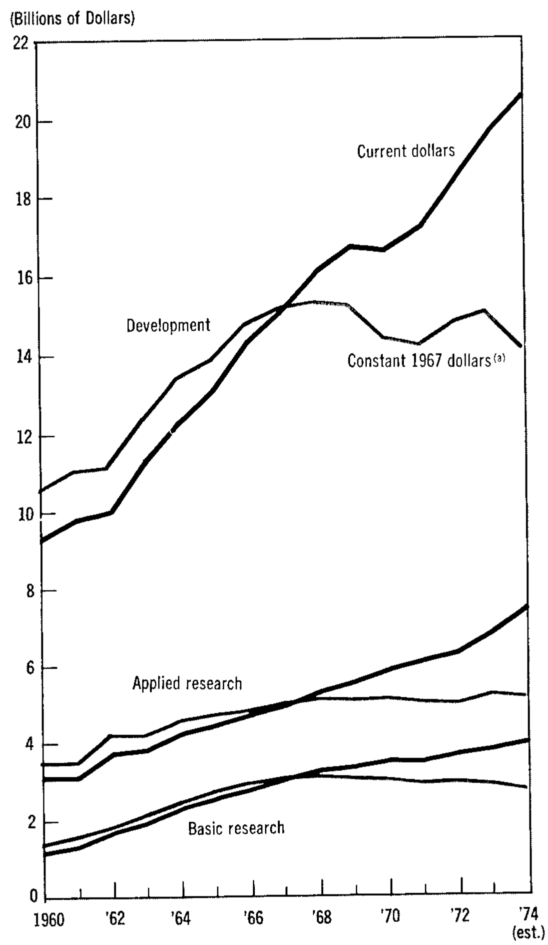
[7] Full-time equivalent basis.

Basic research, applied research, and development

Trends in expenditures for the three categories of R&D are presented in figure 2-6. Development efforts accounted for almost two-thirds of the total R&D expenditures each year during the 1960-74 period, applied research approximately 22 percent, and basic research, over 12 percent.

Current dollar expenditures increased nearly every year for each of the three components. In constant dollars, however, development expenditures leveled off in the late 1960's, and were 7

Figure 2-6
National R&D Expenditures by Character of Work, 1960-74



(a) GNP implicit price deflators used to convert current dollars to constant 1967 dollars.

SOURCE: National Science Foundation.

increased. In 1974, the Government provided 68 percent of the basic research funds, compared with 59 percent in 1960; universities and colleges furnished 11 percent in 1974 and 6 percent in 1960, while industry supplied only 15 percent of the Nation's basic research expenditures in 1974 compared to 28 percent in 1960 (figure 2-7).

In current dollars, 1974 was the peak year for basic research funding from each source. The magnitude of support, however, was insufficient to maintain the level of effort of earlier years as measured by constant dollars. Federal funding in 1974 was down 13 percent from the 1968 high, industry support was 20 percent below its high of 1966, university expenditures were 10 percent lower than in 1972, and funding by nonprofit institutions was down 4 percent.

Applied research depends almost entirely on Government and industry support. Federal support in 1974 accounted for 54 percent of all such expenditures and industry for 41 percent. This pattern has been fairly consistent through the years. For each source of funds for applied research, the 1974 constant dollar expenditures were at or near their highest for the 1960-74 period.

Funding for development in 1974 was supplied equally by the Government and by industry, about 50 percent each, in contrast with 1960 when industry's contribution represented only 32 percent. In current dollars, development expenditures from the Federal Government reached a high in 1974, but in constant dollars were 25 percent below the 1966 peak year and approximately the same as in 1961. Industry support for development, on the other hand, has risen to the extent that the constant dollar high occurred in 1973, followed by a small decline in 1974.

percent lower in 1974 than in 1968, the year of highest funding. Constant dollar expenditures for applied research, on the other hand, were at their highest level in 1973, whereas spending for basic research in 1974 was 10 percent lower than its peak level of 1968.

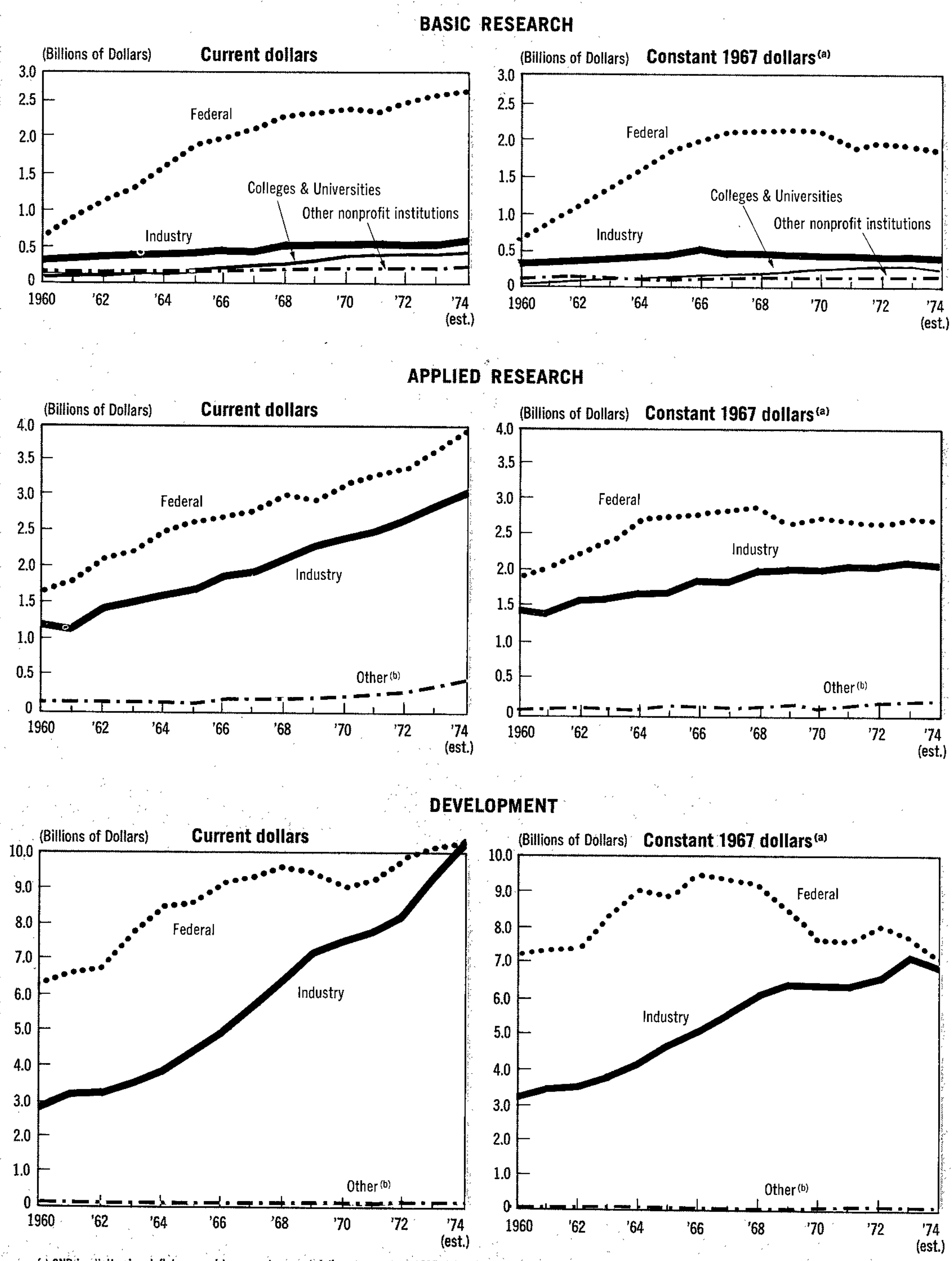
Each component of R&D draws its funding from a different combination of sources which may change over time. Such a shift occurred in the funding of basic research during the 1960-74 period, with the industry role becoming smaller while the contributory roles of the Federal Government and universities and colleges

FEDERALLY FUNDED R&D IN FUNCTIONAL AREAS

The financial resources provided by the Federal Government for R&D reflect the extent to which the Government depends upon R&D in pursuit of a range of national concerns—from such areas as defense, health, and energy to the expansion of basic scientific knowledge. These resources are described below in relationship to total Federal outlays, the R&D component of the "relatively controllable" portion of the Federal

Figure 2-7

National R&D Expenditures, by Character of Work, and Source of Funds, 1960-74



(a) GNP implicit price deflators used to convert current dollars to constant 1967 dollars.

(b) Universities, colleges and other nonprofit institutions combined.

SOURCE: National Science Foundation.

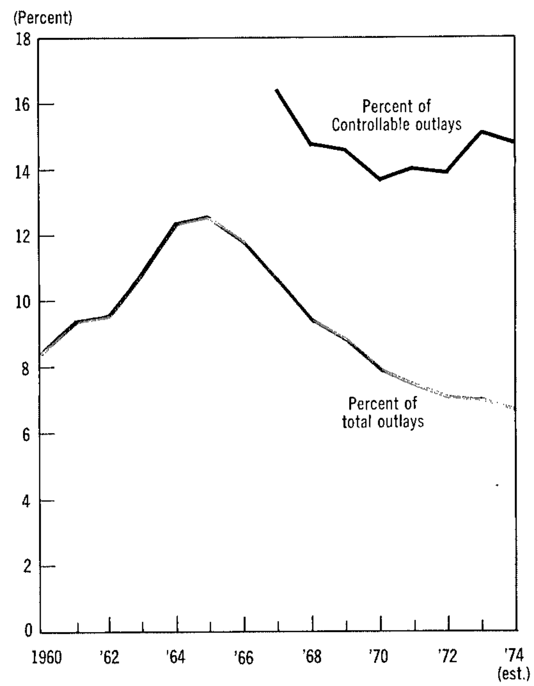
budget, and the principal functional areas toward which R&D is directed.[8]

Total Federal outlays and R&D obligations

Federal expenditures for R&D (including R&D plant), as a percentage of total Federal outlays, declined appreciably after 1965, dropping from 13 percent of the total budget to 7 percent in 1974 (figure 2-8). This reduction results from a mixture of rapid growth in Federal outlays in areas which have small R&D expenditures (e.g., income security and social services), and diminished expenditures for space R&D.

Figure 2-8

Federal Expenditures[a] for Research, Development and R&D Plant, as a Percent of Total Federal Outlays, and as a Percent of the Relatively Controllable Portion of the Federal Outlays, 1960-74



(a) Reported by Federal agencies.

SOURCE: National Science Foundation.

Obligations for R&D may be viewed also in relationship to the controllable portion of the Federal budget. To an increasing degree, expansion of the Federal budget is due to "fixed cost and open ended" programs which increase by law, and are not established by the current budgetary action of either the legislative or the executive branches. These include various programs, such as income security, medical benefits, interest on Treasury bonds, and revenue sharing. When these programs are excluded, the remaining portion of the budget—the relatively controllable portion—is estimated to account for 46 percent ($125.4 billion) of the 1974 Federal budget obligations; in 1967 (the earliest year for which such data are available), the controllable fraction is estimated to have amounted to 65 percent of total obligations.[9] Federal funds for R&D represented 15 percent of the relatively controllable portion of the budget in 1974, down from 16 percent in 1967 but greater than the low of 14 percent in 1970 (figure 2-8).

Areas of Federally funded R&D

R&D funded by the Federal Government can be separated into three categories in terms of broad function: national defense, space exploration, and "civilian" areas (such as energy, the environment, and health). This division is shown in figure 2-9 for Federal obligations.[10]

The most salient aspects of the figure are: (a) the large fraction of total Federal R&D obligations for national defense (52 percent in 1974); (b) the rapid growth of R&D expenditures in civilian areas (up from 24 percent of all Federal R&D obligations in 1969[11] to 34 percent in

[8] Data are available regarding R&D by functional area only for Federal sources. The chapter titled "Industrial R&D and Innovation" discusses R&D expenditures by industries and by product fields.

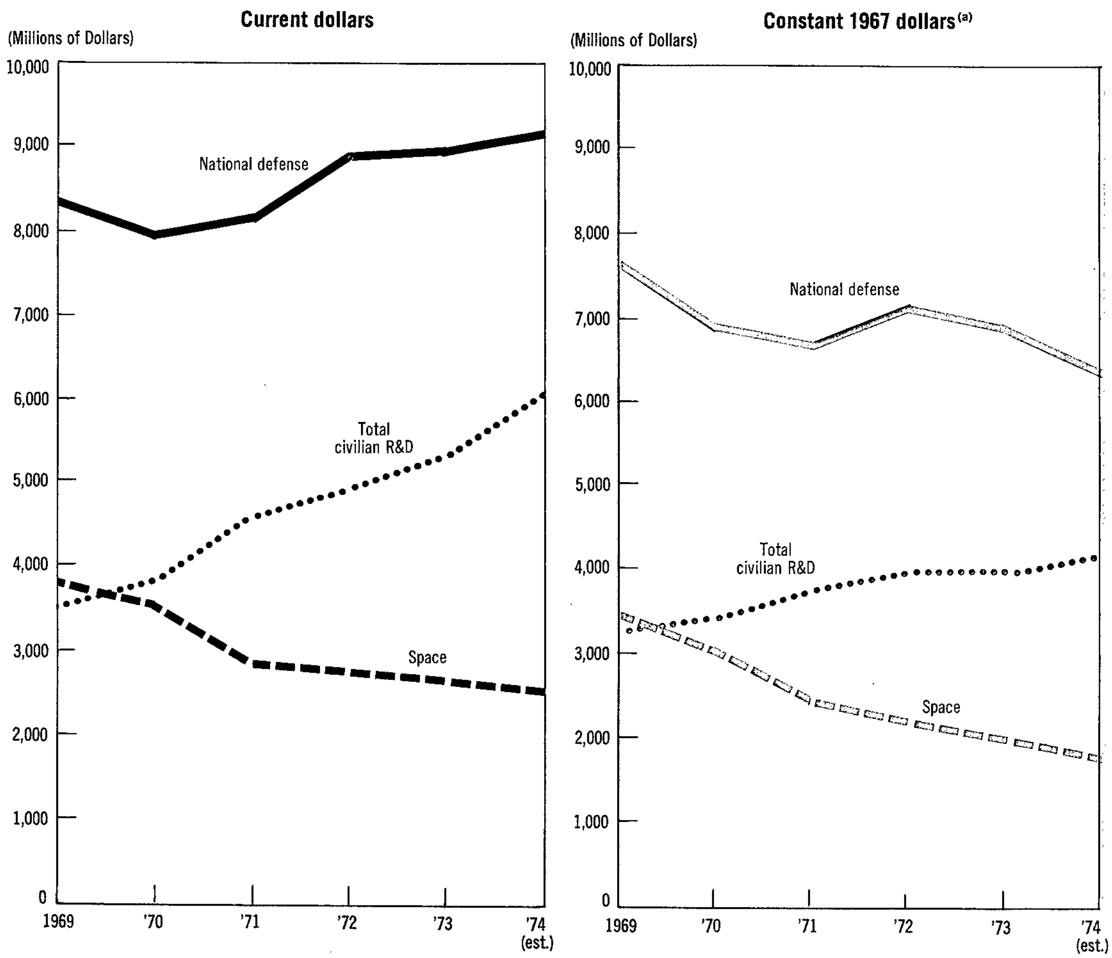
[9] These estimates were obtained from *Federal Funds for Research, Development, and other Scientific Activities*, National Science Foundation, (NSF 74-320). The "relatively controllable" and "uncontrollable" components identified in the NSF report are identical, in concept and numerical value, to the "discretionary" and "mandatory" components defined in *Setting National Priorities—The 1975 Budget*, Brookings Institution, 1975.

[10] See the chapter in this report, entitled, "International Position of U.S. Science and Technology" for a comparison of the U.S. with other countries regarding the distribution of government R&D funds among areas of national goals.

[11] Comparable data are not available for years prior to 1969.

Figure 2-9

Federal Obligations for R&D, by Major Function, 1969-74



(a) GNP implicit price deflators used to convert current dollars to constant 1967 dollars.
SOURCE: National Science Foundation.

1974); and (c) the continuing decline of space R&D (down from 24 percent of total R&D obligations in 1969 to 14 percent in 1974). In the defense area, current dollar obligations for R&D in 1974 were the highest of the period, up 13 percent over their 1969 level; in constant dollars, however, obligations were 17 percent lower in 1974 than in 1969. Civilian R&D, on the other hand, increased in both current and constant dollars, rising 70 percent and 28 percent, respectively. Obligations for space R&D declined 33 percent in current dollars and 49 percent in constant dollars between 1969 and 1974.

The 1974 R&D programs within these three broad categories are described briefly below, first national defense, then space, and finally the civilian category—each in terms of its major components.[12]

National Defense. The 1974 obligations were directed in the main to the development of *missiles, aircraft, defense-related atomic energy, ships and*

[12] For more detailed information, see *An Analysis of Federal R&D Funding by Function,* National Science Foundation, (NSF 74-313).

small craft, and military astronautics. The first subfunction, *missiles and related equipment,* includes efforts related to advanced ICBM's, the Trident submarine-based missiles, and the Safeguard antiballistic missile system. *Aircraft and related equipment* represents work related to the B-1 advanced strategic bomber, the EF-111A electronic warfare support aircraft, the CH-53E helicopter, the A-10 close air support aircraft, the V/STOL aircraft, the F-15 air superiority fighter and the F-14 interceptor aircraft. Two Atomic Energy Commission (AEC) programs make up the *atomic energy* subfunction: weapons R&D and testing activities, and naval reactor development. *Ships, small craft, and related equipment* includes work on the amphibious assault landing craft, the Trident submarine, a prototype surface effects ship, and the patrol hydrofoil missile craft. The *military astronautics* subfunction includes such programs as the NAVSTAR global positioning system, the close air support weapon system, the precision location strike system, and the planning efforts related to using the NASA space shuttle for launching military payloads. The remainder of military R&D obligations are spread across the areas of ordnance, combat vehicles, military sciences, other military R&D, other equipment, and program-wide management and support.

Space Exploration. The principal programs, in terms of magnitude of 1974 obligations, were *manned space flight, space sciences, space technology, and supporting space activities.* The main focus of the *manned space program* is the space shuttle, and the Apollo-Soyuz Test Project to rendezvous and dock U.S. and U.S.S.R. spacecraft. Within the *space sciences,* the lunar and planetary program represents the largest activity, followed by the physics and astronomy program, and the launch vehicle support program. *Space technology* consists of materials and structure research, development of guidance control systems, and development of information processing systems. Propulsion systems technology, both chemical and electric, is also part of this subfunction. *Supporting space activities* are related to operations of tracking and data acquisition networks, and improvement of the capabilities of specialized ground equipment.

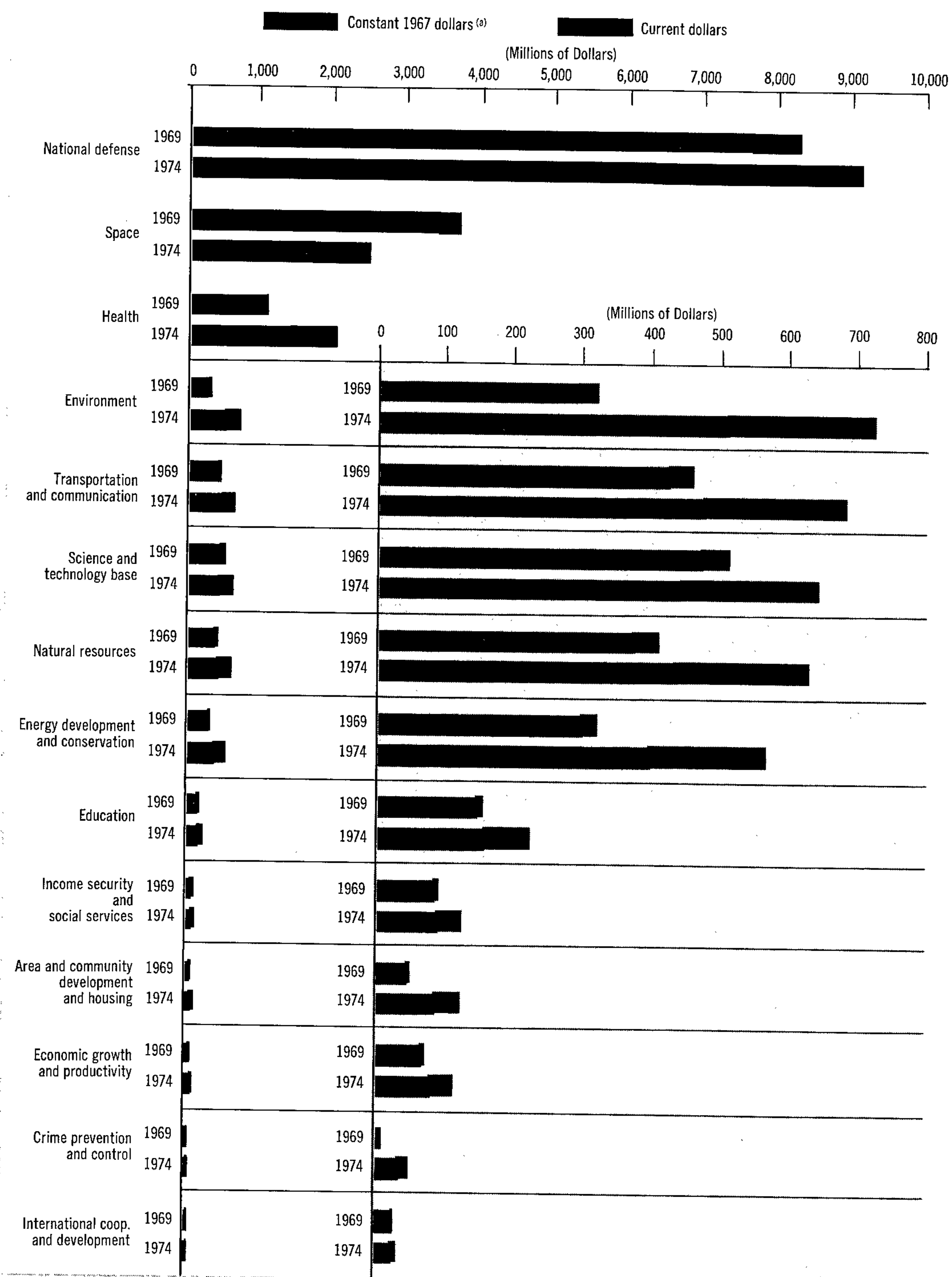
Civilian R&D. The distribution of Federal R&D obligations among the various civilian areas, as well as funds for defense and space, is shown in figure 2-10 for the years 1969 and 1974. The relatively rapid growth in R&D obligations to the civilian sector—up from $3,556 million in 1969 to $6,055 million in 1974—is due primarily to increased spending in the health and environmental areas, the first area accounting for 39 percent and the latter 17 percent of the total growth in the civilian sector. The several areas comprising this sector are listed in the following table, along with the proportion of funds going to each.

Distribution of Federal R&D obligations among civilian areas, 1974

Areas	Percent of total R&D	Percent of civilian R&D
Health	11.7	34.4
Environment	4.2	12.2
Transportation and communication	3.9	11.4
Science and technology base	3.6	10.7
Natural resources	3.6	10.4
Energy development and conversion	3.2	9.5
Education	1.3	3.8
Income security and social services	.7	2.2
Area and community development & housing	.7	2.1
Economic growth and productivity	.7	1.9
Crime prevention and control	.3	.9
International cooperation and development	.2	.6

Figure 2-10

Federal Obligations for R&D, by Function, 1969 and 1974



(a) GNP implicit price deflators used to convert current dollars to constant 1967 dollars.

SOURCE: National Science Foundation.

The R&D programs in the largest of these areas are described below in abbreviated form.

(1) **Health,** which consists of the subfunctions of *biomedical research, mental health, delivery of health care,* and *drug prevention and rehabilitation. Biomedical research,* which accounts for some 90 percent of all Federal obligations for health-related R&D, includes activities of the nine National Institutes of Health which deal with specific chronic and communicable diseases as well as general medical sciences. Among these institutes, the cancer, heart and lung, and child health and development research programs have grown the most rapidly in recent years. The second category, *mental health,* falls entirely within the purview of the National Institute of Mental Health within HEW's Alcohol, Drug Abuse, and Mental Health Administration. This activity received about five percent of the 1974 Federal obligations for health-related R&D. *Delivery of health care* is composed of a number of HEW programs with widely different missions including the health services research and evaluation program, the Center for Disease Control, the maternal and child health services program, and the National Health Statistics program. The last category of health-related activities is *drug prevention and rehabilitation,* which includes the drug abuse and alcoholism research activities of HEW, the drug abuse program of the VA, and the Special Action Office for Drug Abuse and Prevention.

(2) **Environment,** which encompasses three areas: *pollution control and abatement* programs of the Environmental Protection Agency (EPA), the Atomic Energy Commission (AEC), and the Department of Transportation (DOT); research aimed at *understanding, describing, and predicting the environment* supported by the National Aeronautics and Space Administration (NASA), the National Science Foundation (NSF), and the National Oceanic and Atmospheric Administration (NOAA); and *environmental health* programs within the AEC, the EPA, the Bureau of Mines of the Department of the Interior, the National Institute of Environmental Health Sciences, the National Institute for Occupational Safety and Health, and the Food and Drug Administration.

(3) **Transportation and Communication,** which consists of R&D in *air, ground, water, and multimodal transportation* along with *communications*-related R&D. *Air transportation* R&D is composed of NASA's aeronautical research and technology program, and R&D supported by the Federal Aviation Administration and the Civil Aeronautics Board. *Ground transportation* R&D includes the R&D efforts of the following DOT programs—the Urban Mass Transportation Administration, the National Highway Safety Administration, and the Federal Railroad Administration. R&D in *water* and *multimodal transportation* includes programs of the Maritime Commission, the U.S. Coast Guard, and the Office of the Secretary of DOT. The *communications* subfunction is composed for the most part of NASA's communications satellite program.

(4) **Science and Technology Base,** which is aimed at expanding and strengthening the Nation's scientific base, is for the most part considered to be untargeted research. Over three-fourths of this function is accounted for by NSF's Scientific Research Project Support Program and AEC's Physical Research Program. Also included in this function are NSF's National Research Centers, the Smithsonians's Basic Research Program, and the National Bureau of Standards (NBS) National Physical Measurement System.

(5) **Natural Resources,** includes R&D activities aimed at improving the utilization of the Nation's *food, mineral, water, land, and recreation resources.* The major programs under *food resources* are the Department of Agriculture's (USDA) research into the production, marketing and use of agricultural products, and NOAA's ocean fisheries and living marine resources program. The *mineral resources* category is composed of four Department of Interior programs including the areas of mining technology, geological and mineral resource surveys, and metallurgy research. R&D in *water resources* is concentrated in the Department of the Interior under the Geological Survey and the Office of Water Resources. The *land resources* category consists of 10 relatively small programs; the largest two are the timber management research and the forest insect and disease research, both of the USDA. The *recreation resources* subfunction is composed of two Department of Interior programs—wildlife resources management

and sport fisheries resources management. This Natural Resources function also includes a *multi-resource* R&D effort which is defined as the earth observation program of NASA and the sea grant program of NOAA.

(6) **Energy Development and Conversion,** which consists of subfunctions related to four sources of energy—*nuclear, fossil fuels, solar and geothermal*—and to one category for *other* energy R&D. *Nuclear* energy activities are concentrated in the AEC programs related to reactor development and safety, controlled thermonuclear research, and nuclear materials production. *Fossil fuel* research is composed of coal, petroleum, and oil shale R&D efforts supported by the Department of the Interior. Both *solar* and *geothermal* energy subfunctions are represented by the NSF projects in these areas. The *other* energy development and conversion subfunction is made up of 13 programs including AEC's applied energy technology program, the NSF's energy research and technology program, and Interior's energy conservation and analysis program.

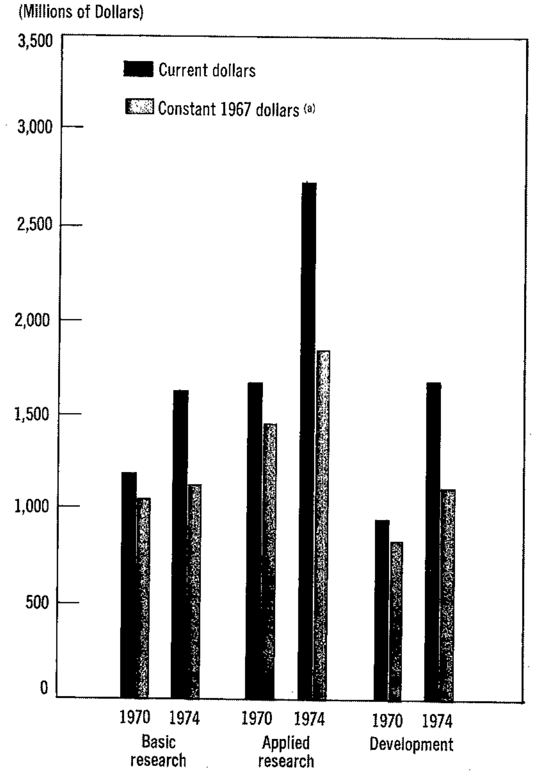
(7) **Education,** is composed of several HEW programs including the National Institutes of Education, the Office of Education, and the Office of Human Development; and the NSF programs of Scientific Education Improvement and Institutional Improvement. Educational R&D is spread among a wide range of efforts, including the development of improved curricula and individualized instructional materials, better understanding of the learning process, and the motivation of disadvantaged children.[13]

Basic research, applied research, and development in civilian R&D

Federal obligations for R&D in civilian areas are directed primarily to basic and applied research rather than to development (figure 2-11), a distribution pattern quite different from the defense and space sectors described below and from the overall national R&D effort (figure 2-6). In 1974, funds for research accounted for 72 percent of all civilian R&D obligations by the

Figure 2-11

Federal Obligations for Civilian R&D, by Character of Work, 1970 and 1974



(a) GNP implicit price deflators used to convert current dollars to constant 1967 dollars.
SOURCE: National Science Foundation.

Federal Government, with 45 percent going for applied research and 27 percent for basic research. A comparison of 1970 obligations with those of 1974 indicates, however, a shift toward greater emphasis on development and applied research and relatively less on basic research. Between 1970-74, Federal obligations in current dollars for development and applied research rose by 72 percent and 64 percent, respectively, compared with a 36 percent increase for basic research (figure 2-11).

Federal obligations for civilian basic research are concentrated in a few functional areas; 83 percent of these obligations in 1974 were in the areas of health, natural resources, and the science and technology base. Of these three areas, only one—health—had funding increases between 1970-74 for basic research which were

[13] For information on the R&D programs in the other five areas of the civilian sector, see *An Analysis of Federal R&D Funding by Function, 1969-75,* National Science Foundation, (NSF 74-313).

sufficiently large to offset the effects of inflation during the period.[14]

R&D in the defense and space sectors, as noted above, differs from the civilian sector in the distribution of funds for basic research, applied research, and development. In these sectors, development accounts for most of the R&D obligations, in contrast to civilian R&D where funds are directed primarily to research—basic and applied. In 1974, 80 percent of the funds for defense R&D were allocated to development activities, 17 percent to applied research, and 3 percent to basic research. And in the space sector, 61 percent of the obligations went for development, 27 percent for basic research, and 12 percent for applied research.

RESEARCH EQUIPMENT AND FACILITIES

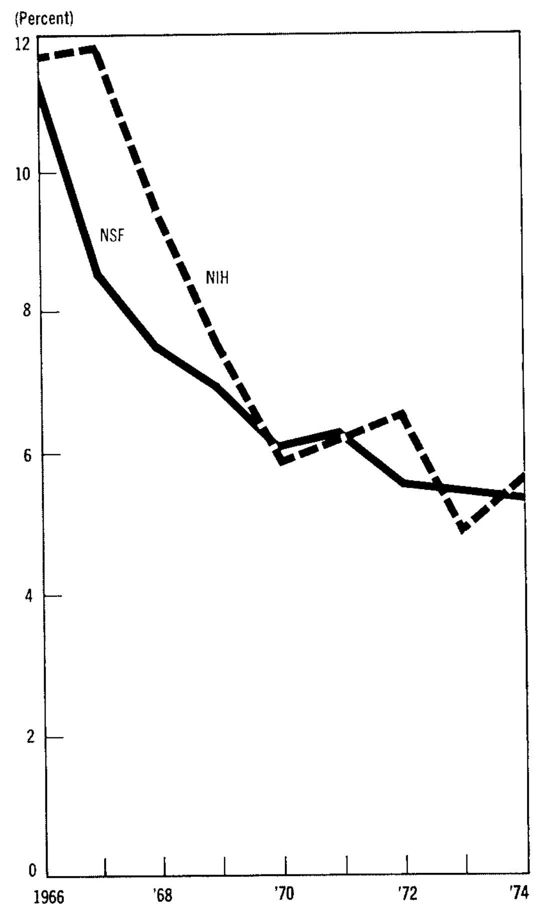
Along with human and financial resources, research equipment and facilities constitute the elements essential for performing R&D. Research instrumentation provides the means for accurate measurement and observation, and facilitates data collection and analysis. Progress in science depends increasingly upon such equipment, as the phenomena under study become more fundamental and inaccessible to observation by the unaided human senses. Laboratories and support facilities provide the fixed equipment and physical plant necessary for R&D. Requirements in this area change as science advances, as new areas of research emerge, and as R&D is directed toward new objectives and problems. The excellent equipment and facilities heretofore available to the R&D community in this country are regarded generally as prime elements contributing to the strong international position of U.S. science.

Research equipment

The Federal Government is a major source of funding for the acquisition and maintenance of laboratory equipment, a large portion of which is included in research grants to provide the equipment needed for performing the research. In the two Federal agencies which provide the majority of such support, the National Institutes of Health and the National Science Foundation, the proportion of grant funds allocated for permanent laboratory equipment declined over the entire 1966-74 period. In both agencies, the proportion fell from approximately 11 percent in 1966 to some 5 percent in 1974 (figure 2-12). For the National Science Foundation, this decline represents a 14 percent reduction in current dollar obligations (and 40 percent in constant dollars) for research equipment between 1966 and 1974, despite the 54 percent increase in current dollar obligations (and 22 percent in constant dollars) between 1970 and 1974 (figure 2-13).[15]

Figure 2-12

Proportion of NSF and NIH[a] Research Project Grant Funds Allocated for Permanent Laboratory Equipment, 1966-74



[a] Includes the National Cancer Institute, the National Institute of General Medical Sciences and the National Heart and Lung Institute.

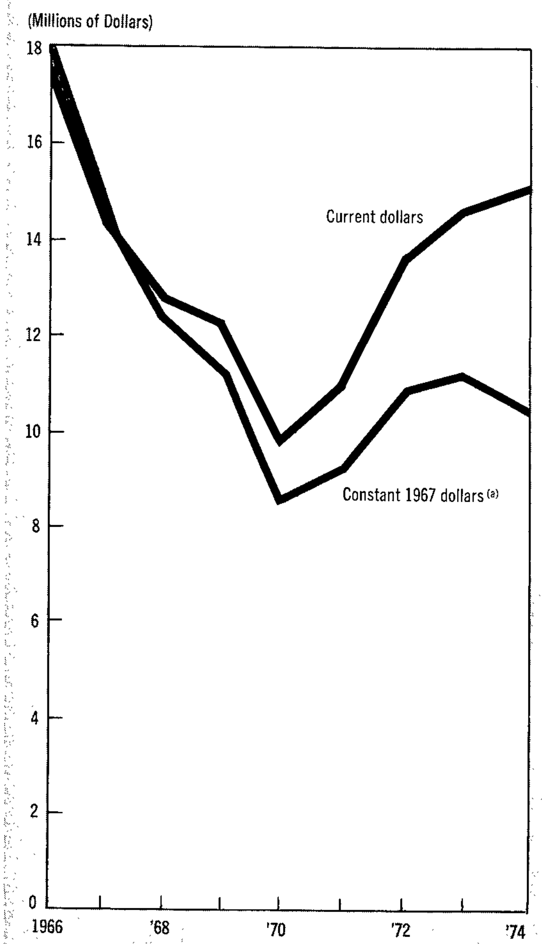
SOURCE: National Science Foundation and National Institutes of Health.

[14] Special analysis prepared from *An Analysis of Federal R&D Funding by Function*, National Science Foundation, (NSF 74-313).

[15] Comparable data are not available for the National Institutes of Health.

Figure 2-13

NSF Obligations for Permanent Laboratory Equipment, 1966-74



(a) GNP implicit price deflators used to convert current dollars to constant 1967 dollars.
SOURCE: National Science Foundation.

There are other sources of support for research equipment within the Federal Government as well as the private sector, but information on the extent and other characteristics of such support is not available. General concern, however, has been expressed by the scientific community that funds for laboratory equipment have been deficient in recent years, with the result that the quality of research instrumentation is declining. Information appearing to substantiate this concern was obtained in a 1971 study of equipment needs in universities. The study concluded that research equipment was inadequate in each of the 10 scientific fields surveyed, and estimated the amount required to fill immediate needs to be some $275 million in these fields.[16]

R&D plant

Resources in this area go for the acquisition, construction, and major repair of R&D facilities, as well as for the purchase of large fixed equipment such as reactors, wind tunnels, and radio telescopes. Data are available for only one source of support for R&D plant—the Federal Government. Funds from this source, however, are believed to represent a large part of the total investment in this area, although the relative size of the Federal role may vary among different sectors.

Federal expenditures for R&D plant are shown in figure 2-14. The rapid growth of expenditures during the early 1960's was due almost entirely to the expansion of intramural facilities of the National Aeronautics and Space Administration (NASA); the decline in later years reflects, largely, the completion of these facilities. The up-turn in expenditures after 1972 was produced by increased spending on the part of the Atomic Energy Commission, NASA, and the Department of Health, Education, and Welfare; funds from these agencies were directed in the main to industry and Federal intramural facilities.

In recent years, over three-fourths of the Federal support for R&D plant has been allocated to two sectors—Federal intramural laboratories and industry (figure 2-15). The intramural laboratories received 42 percent of the funds in 1974, industry 35 percent, Federally Funded Research and Development Centers (FFRDC's) administered by universities 14 percent, universities and colleges 5 percent, and other nonprofit institutions 4 percent.

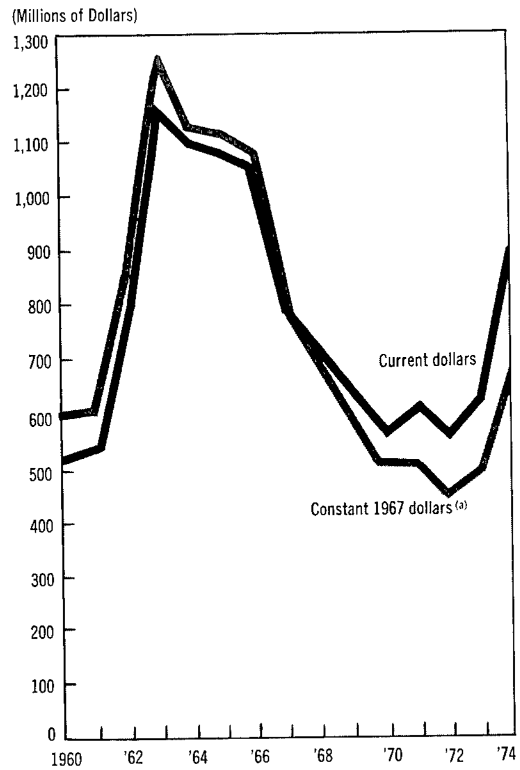
Federal support for R&D plant has not kept pace with funds for total R&D, as is shown in figure 2-16, which presents the relationship between Federal funds for R&D plant as a percent of total Federal obligations for R&D. The early rise and latter decline in this ratio for

[16] *Survey of Research Equipment Needs in Ten Academic Disciplines,* National Science Foundation and National Academy of Sciences, 1972.

[17] Data for those FFRDC's administered by industry and other nonprofit institutions are not separately available.

Figure 2-14

Federal Expenditures for R&D Plant, 1960-74

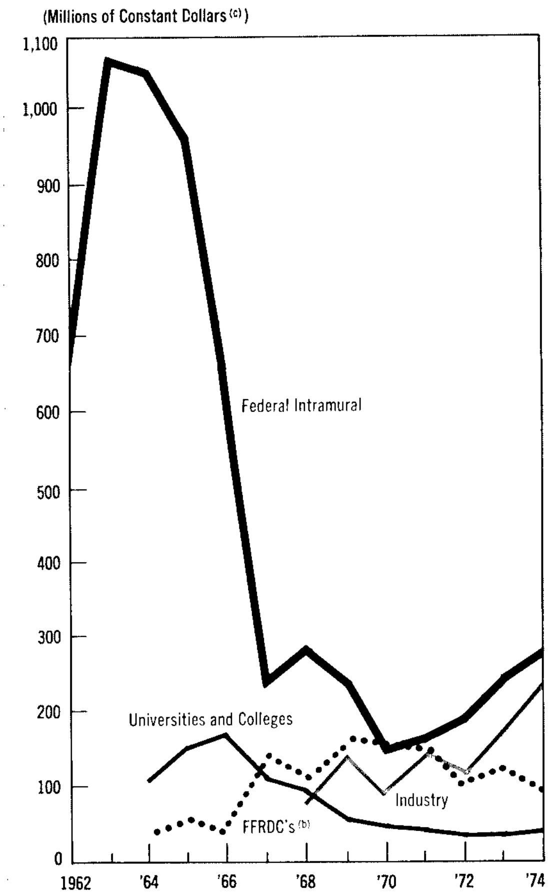


(a) GNP implicit price deflators used to convert current dollars to constant 1967 dollars.

SOURCE: National Science Foundation.

Figure 2-15

Federal Obligations for R&D Plant, by Performer, 1962-74 (a)



(a) Data for specific performers are not available for earlier years.
(b) Federally Funded Research and Development Centers administered by universities and colleges.
(c) GNP implicit price deflators used to convert current dollars to constant 1967 dollars.

SOURCE: National Science Foundation.

the Federal intramural laboratories is due mainly to a like pattern of change in NASA funds for R&D plant. The ratio for university FFRDC's fluctuated from year to year, ending in 1974 at 17 percent. In universities and colleges, on the other hand, the ratio decreased steadily from a peak in 1966 of 9 percent to a low of 2 percent in 1974.

DISSEMINATION OF R&D RESULTS

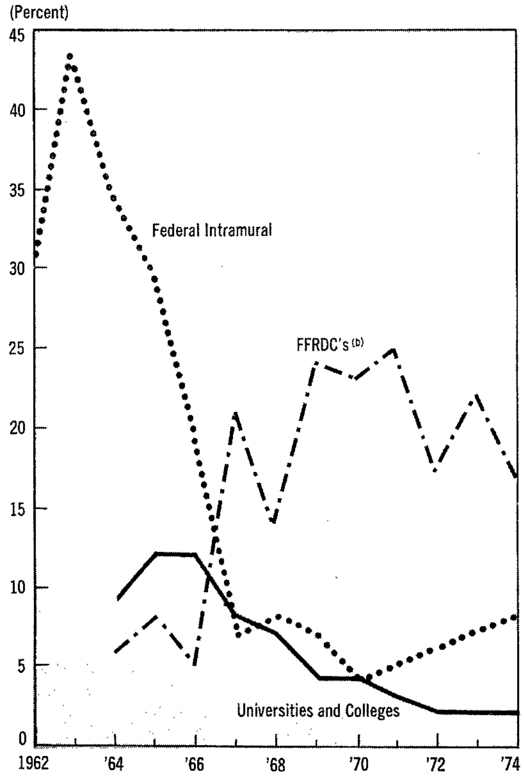
The publication and dissemination of the scientific knowledge and technical information resulting from R&D are essential steps toward realizing the full benefits from the R&D investment. Such communication may not only prevent duplication of effort, but may also hasten further advances in science and shorten the time between R&D and application.[18]

The total national resources directed to such activities are not known. Some information, however, is available on the funds provided by the Federal Government in this area.

[18] For information on Federal programs aimed at disseminating and transferring scientific and technical knowledge to potential users in the private and public sector, see *Federal Technology Transfer Directory of Programs, Resources, Contact Points*, Federal Council for Science and Technology, Committee on Domestic Technology Transfer, 1975.

Figure 2-16

Federal Obligations for R&D Plant as a Percent of Federal Obligations for Total R&D, by Selected Performers, 1962-74[a]



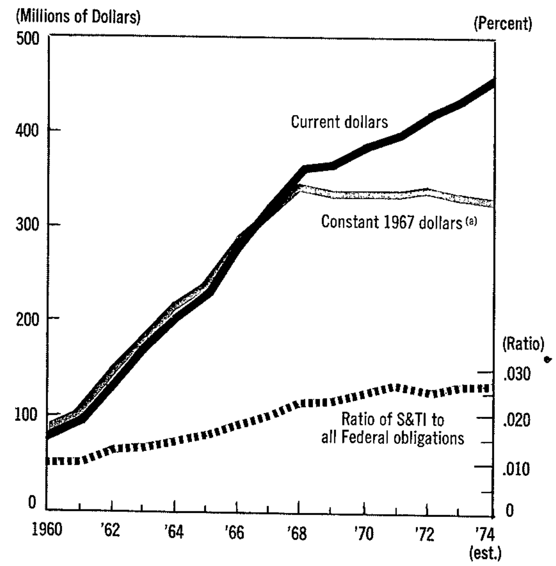
[a] Data for specific performers are not available for earlier years.
[b] Federally Funded Research and Development Centers administered by universities.
SOURCE: National Science Foundation.

Scientific and technical information (S&TI) activities consist of: (1) documentation, reference, and information services; (2) publication and distribution; (3) symposia and audio visual media; (4) R&D in information sciences; and (5) information systems, techniques, and devices. Federal support for these activities increased six fold over the 1960-74 period[19] (figure 2-17); in terms of constant dollars, however, 1968 was the year of highest funding followed by a leveling off through 1974. The ratio of total S&TI obligations to Federal R&D grew from .010 in 1960 to .025 in 1970, and remained approximately at that level through 1974 (figure 2-17).

Several agencies support programs in this area. Those which account for most of the Federal support are indicated in figure 2-18, which presents the obligated funds from each. The Department of Defense, through such programs as the Defense Documentation Center, supplied one-third of all Federal funds for S&TI in 1974. The Department of Commerce provided 20 percent of the total, much of which is accounted for by the National Technical Information Service. A similar amount comes from a variety of programs in the Department of Health, Education, and Welfare, a major one being the National Library of Medicine.

Figure 2-17

Federal Obligations for Scientific and Technical Information Activities, Compared with Total Federal R&D Obligations, 1960-74

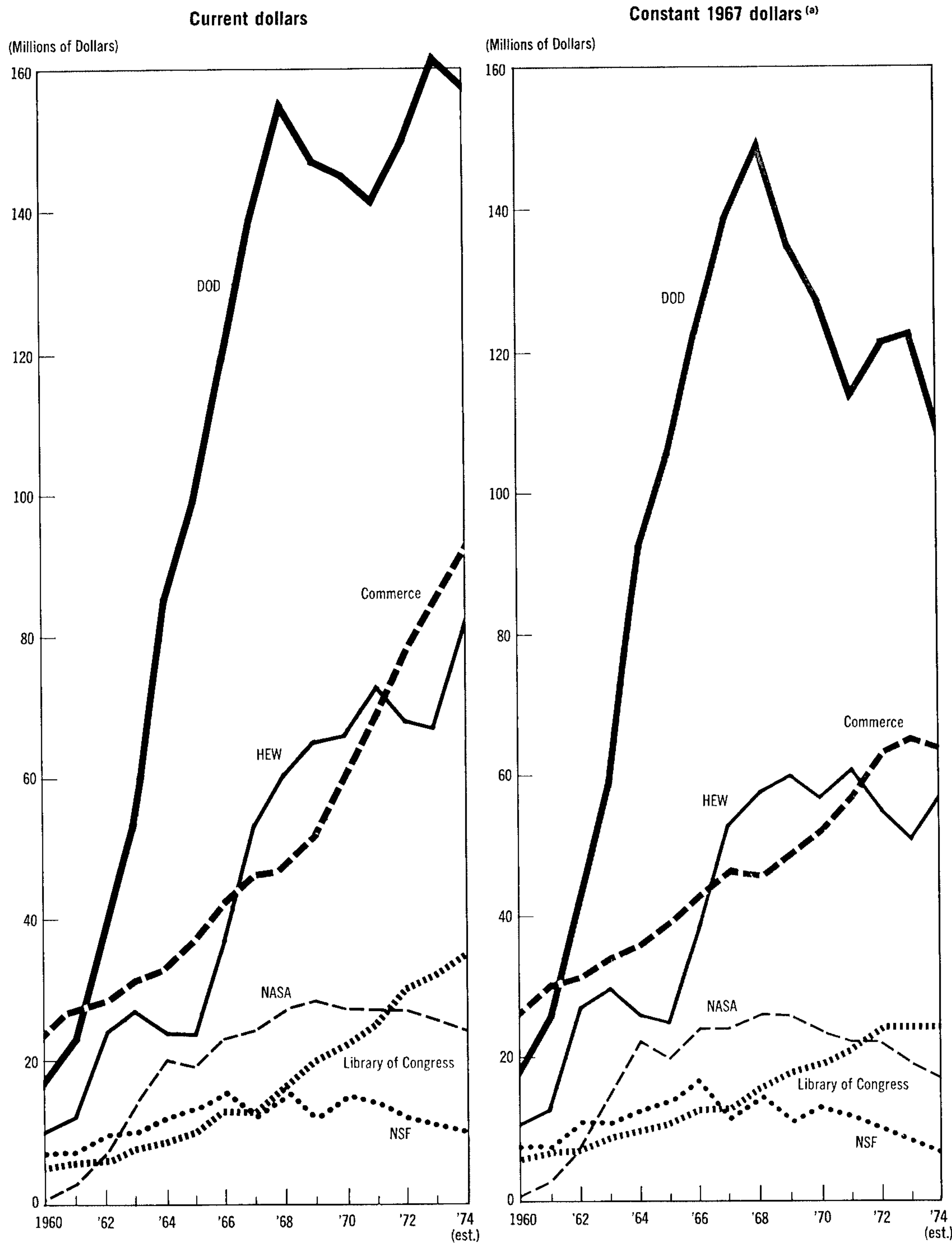


[a] GNP implicit price deflators used to convert current dollars to constant 1967 dollars.
SOURCE: National Science Foundation.

[19] Available data reflect only a portion of the Federal support for all S&TI activities, in that they include only the direct obligations for S&TI and not the support provided through R&D grants and contracts.

Figure 2-18

Federal Obligations for Scientific and Technical Information Activities, by Selected Agency, 1960-74



(a) GNP implicit price deflators used to convert current dollars to constant 1967 dollars.

SOURCE: National Science Foundation.

Basic Research

Basic Research

INDICATOR HIGHLIGHTS

- The Nation's total expenditures for basic research rose continually during the 1960-74 period in current dollars; in constant 1967 dollars, funds for basic research in 1974 were equal to the 1965 level, and almost 13 percent lower than the peak year of 1968.
- Universities accounted for approximately 55 percent of the Nation's total expenditures for basic research in 1974 (versus 37 percent in 1960), followed by the Federal Government and private industry at some 15 percent each, and other sectors with the remainder.
- The Federal Government provided the largest share of support for basic research during the 1960-74 period, increasing from nearly 60 percent of all such funds in 1960 to almost 70 percent in 1974; industry's share declined from 28 percent in 1960 to 15 percent in 1974, and the universities' share increased from 6 to 11 percent over this period.
- Funds provided by the Federal Government for basic research increased each year (except for 1971) in current dollars, but declined 13 percent between 1968 and 1974 in constant dollars; the largest reductions in constant dollars were recorded in the physical sciences which declined approximately 25 percent between 1969 and 1974.
- University expenditures for basic research (from all sources of support) rose continuously in current dollars between 1960-74, but declined some 5 percent in constant dollars between 1968 and 1974; this decline is due to reduced growth of Federal support in combination with inflation.
- Basic research expenditures by academic institutions in 1974 were concentrated in the life sciences (51 percent of all expenditures), engineering (12 percent), physical sciences (13 percent), social sciences (8 percent), and the environmental sciences (7 percent).
- Federal support for basic research in universities, which accounted for 70 percent of all such funds in 1974, increased in current dollars between 1964-74 in the broad fields of science and engineering; the level of research effort as reflected by constant dollar expenditures, however, was lower in each field in 1974 than in previous years, with the largest reductions occurring in engineering and the physical sciences.
- Federal support for universities in 1974 was provided primarily through six agencies—NSF, HEW, DOD, USDA, AEC, and NASA—with no more than two agencies supplying at least 70 percent of all Federal basic research support in each major field of science; the NSF provided either the largest or second largest amount of funding among these agencies in each field.
- Expenditures for basic research per scientist and engineer in doctorate-granting institutions were almost 30 percent lower in constant dollars in 1974 than in 1968; the largest decline was in physics, where reductions were nearly 40 percent from 1966 to 1974.
- Federal laboratories accounted for 16 percent of the total national expenditures for basic research in 1974; current dollar expenditures by these laboratories increased throughout most of the 1960-74 period, but the level of research effort in terms of constant dollars was some 20 percent lower in 1974 than in 1970, the year of highest real expenditures.
- Private industry was responsible for 16 percent of the total national expenditures for basic research in 1974; although current dollar expenditures have risen, particularly since 1972, inflation reduced real expen-

ditures in 1974 to approximately the same level as 1961.

- The number of research publications from major fields of science increased generally throughout the 1960's, but leveled off in several fields in the early 1970's; publication output in chemistry, engineering, and physics, for example, has remained at a nearly constant level in recent years.

- Universities are by far the largest producers of published research reports with some 75 percent of the total in 1973, followed by the Federal Government and private industry with approximately 10 percent each, and other nonprofit institutions with 5 percent.

- Basic research contributes increasingly to technological innovation, as reflected by the growing number of citations to research in patents associated with major advances in technology; the frequency of such citations increased 17 percent between the 1950's and 1960's, while citations to other patents declined by almost 25 percent.

- Research performed in universities is most frequently cited as the origin of patented technological advances, accounting for almost 55 percent of the cited research in recent years and replacing industry as the prime sector in which such research is performed.

Basic research is the quest for fundamental understanding of man and nature, in terms of scientific observations, concepts, and theories. Such research is generally motivated by curiosity and the desire to advance scientific knowledge, with the opportunities for its advancement determined primarily by the existing state of scientific understanding itself, rather than by practical need or potential application. As an activity, this research ranges from efforts of teams of scientists working with large facilities such as particle accelerators to the efforts of individual scientists using little or no research equipment. And basic research, being international in its nature, joins the activities of scientists from many countries.[1]

Although curiosity is frequently the prime motive of the individual scientist for performing research, potential applications often underlie the private and public support of basic research. There is as yet, however, no method for correlating the cost of such research with its total returns—intellectual, economic, and social. But the many and varied uses of basic research suggest that the benefits may be substantial, particularly in comparison with the relatively small investment involved. The findings of basic research represent much of the objective knowledge of the physical and social world which forms a major part of the educational curriculum of the general population, while both the results and the conduct of such research constitute the core of advanced education in the sciences and engineering. Basic research provides the fundamental knowledge on which modern technology increasingly depends. This research, in addition, supplies indispensable knowledge for planning and directing the rest of the R&D effort. Finally, the maintenance of a wide spectrum of basic research can provide the new knowledge needed for responding to challenges in the future—challenges which may not be foreseen at present.

Indicators of the state of basic research presented in this chapter consist largely of the financial resources committed to research and preliminary measures of outputs and their application in industrial technology. The "input" indicators provide information on national expenditures for basic research, the extent of research performed in universities and other sectors, and trends in expenditures for basic research in the various fields of science. "Output" indicators include publications of scientific research produced by different sectors in major fields of science, and measures of the extent to which such research underlies advances in technology.

The present set of indicators are deficient in a number of major aspects. They do not encompass substantive aspects of basic research, such as advances in knowledge achieved in the various scientific disciplines. The indicators, further-

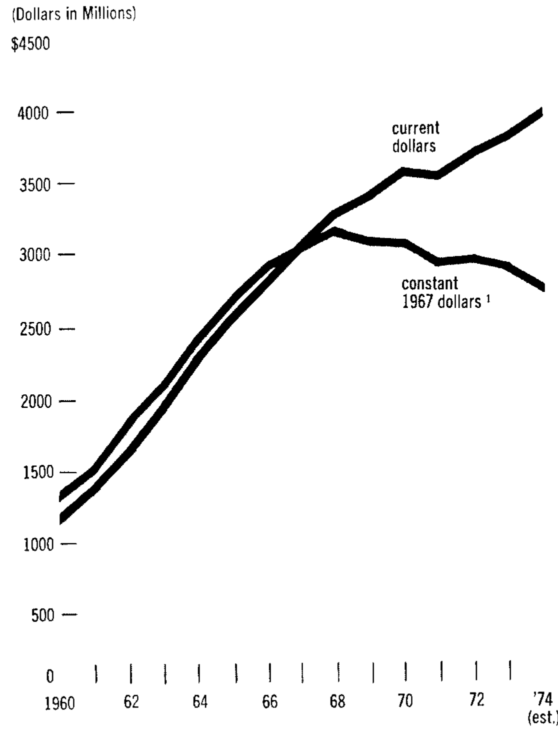
[1] For further discussion of international aspects of science, see the chapter entitled, "International Indicators of Science and Technology" in this report.

more, do not identify the wide applications made of the results of this research. Nor do they represent the economic and social returns from the varied uses made of its cumulative findings. The present indicators, in addition, do not include measures of the effectiveness, or productivity, of the research activity.

Besides these deficiencies, there are other limitations in regard to the data used for the present indicators. There is, for example, uncertainty regarding the precision with which "basic" research can be distinguished from "applied" research. A particular research effort may be identified as basic or applied, depending on whether the classification is made by the sponsor of the research or by the organization performing it. Furthermore, differences among sectors in the assignment of costs to basic research make it difficult to compare expenditures and the magnitude of research efforts among the sectors. Industrial firms, for example, include in their reported expenditures for basic research an annual depreciation cost of the facilities used in the research; universities and Federal laboratories do not. The construction costs of large, Government-financed research facilities such as the National Accelerator Laboratory are not included as basic research expenditures, whereas NASA, in figuring the costs of research using expendable space probes, includes the costs of spacecraft and launch vehicles (in compliance with NSF reporting requirements).

Figure 3-1

Basic Research Expenditures, 1960-74



[1] GNP implicit price deflators used to convert current dollars to constant 1967 dollars.
SOURCE: National Science Foundation.

RESOURCES FOR BASIC RESEARCH

The Nation's total expenditures for basic research increased continuously during the 1960-74 period, rising from $1.2 billion to $4.0 billion in current dollars (figure 3-1). In recent years, however, this growth has not been large enough to offset the eroding effect of inflation. As a result, the actual level of basic research activity—as reflected approximately by expenditures in constant dollars—peaked in 1968 and declined in subsequent years.[2] By 1974, expenditures for basic research were at their 1965 level in constant dollars, and 13 percent less than in 1968.

The proportion of all R&D expenditures reported for basic research has remained essentially constant at some 13 percent since 1965, after rising during the early 1960's.[3]

Expenditures by performer

There are four major sectors of the research community which perform basic research: private industry, Federal laboratories, universities and colleges (and the Federally Funded Research and Development Centers they administer), and other nonprofit institutions which conduct R&D. Because these sectors have differing missions and purposes, two different definitions of basic research are used for data

[2] The use of constant 1967 dollar expenditures to approximate the level of research activity is discussed in the preceding chapter entitled, "Resources for Research and Development."

[3] *National Patterns of R&D Resources, 1953-75*, National Science Foundation (NSF 75-307).

collection. For all but the industry sector, the definition of basic research stresses that such activity be directed toward increases of knowledge in science with the primary aim of the investigator being ". . .a fuller knowledge or understanding of the subject under study, rather than a practical application thereof."[4] For the industrial sector, to take account of an individual company's commercial goals, basic research is defined as ". . .original investigations for the advancement of scientific knowledge . . .which do not have specific commercial objectives, although they may be in fields of present or potential interest to the reporting company."[4]

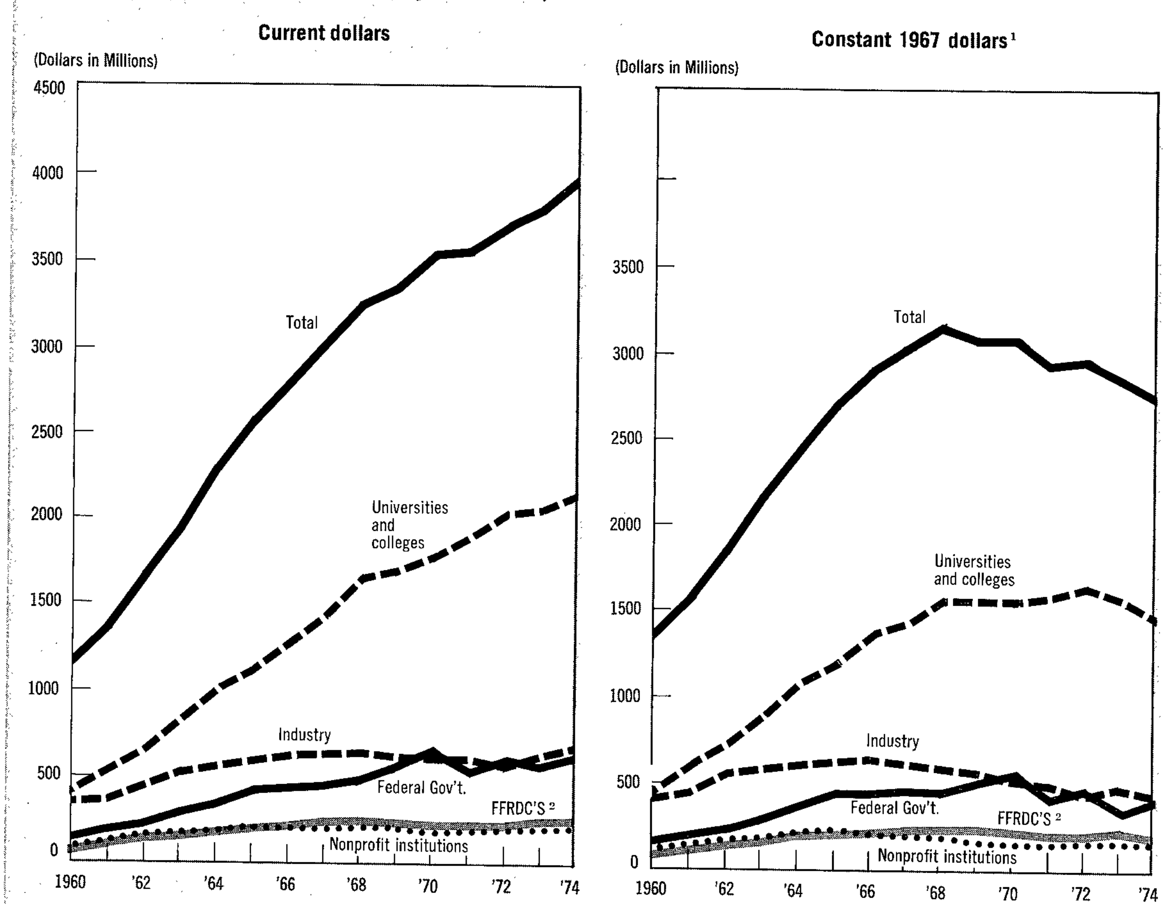
[4] *Ibid.*

The varying levels of basic research expenditures from 1960 to 1974 are shown in figure 3-2 for the R&D-performing sectors. It should be noted that the growth in current dollar expenditures between 1968-74 was not sufficient to compensate for inflation in any of these major sectors.

Constant dollar expenditures for basic research leveled off in the late 1960's for most sectors, and fluctuated around that level in subsequent years. The largest proportional declines between the year of peak funding and 1974 were in industry (31 percent), whereas the smallest percentage decline (9 percent) occurred in universities and colleges.

Figure 3-2

Basic Research Expenditures, by Performer, 1960-74



[1] GNP implicit price deflators used to convert current dollars to constant 1967 dollars.
[2] Federally Funded Research and Development Centers administered by universities.
SOURCE: National Science Foundation.

The distribution of the total funds expended for basic research changed significantly among the sectors during the 1960-74 period. The fraction of the total accounted for by universities and colleges increased from 37 percent in 1960 to 54 percent in 1974, while industry's fraction fell from 32 to 16 percent. There was little change in the distribution of such expenditures among the other sectors.

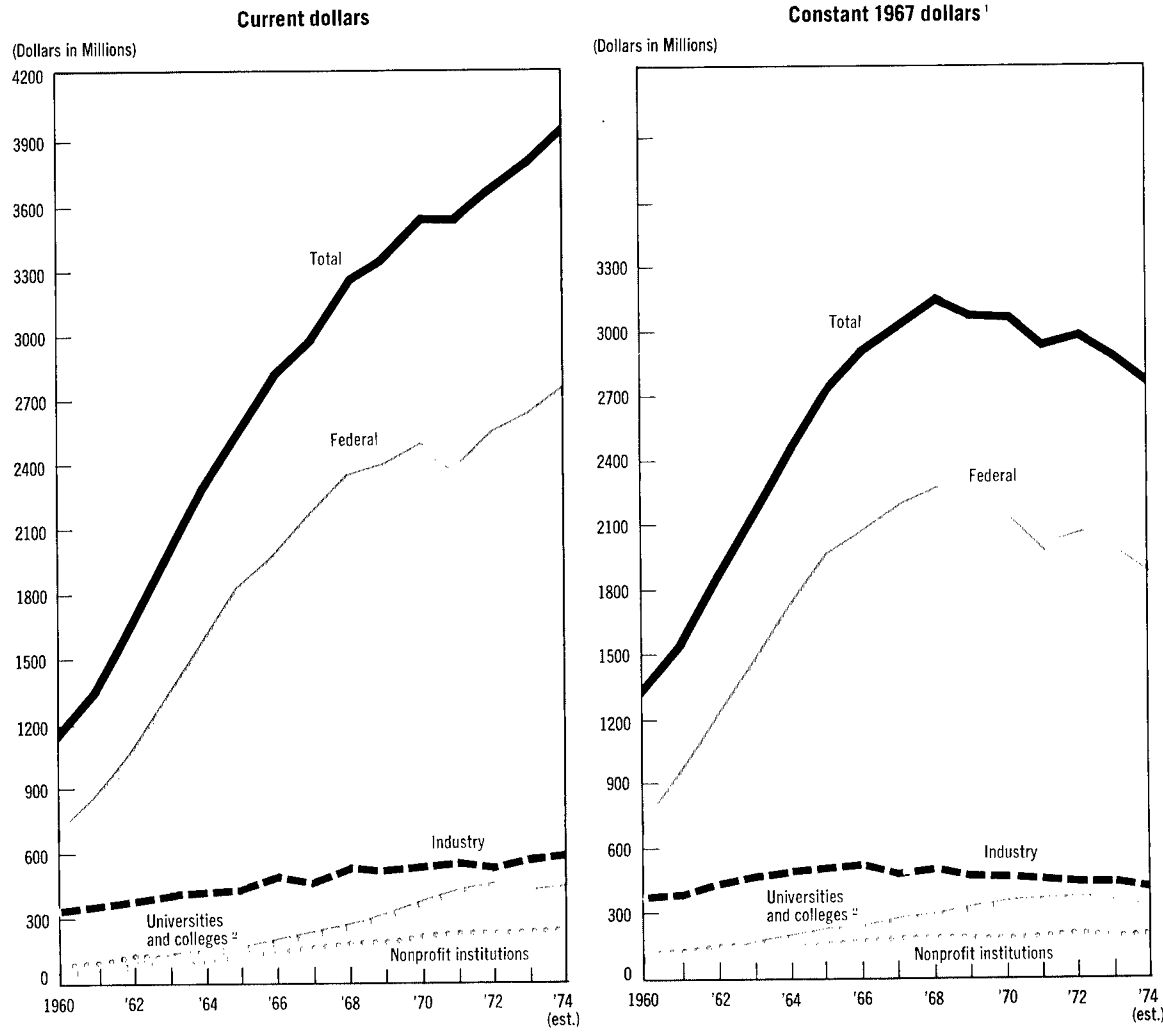
Basic research support by source of funds

The sources of expenditures for basic research are the Federal Government, industry, universities, and nonprofit institutions. Funds supplied for such research by these sources are shown in figure 3-3.

Basic research support from all sources increased in current dollars throughout most of

Figure 3-3

Basic Research Expenditures, by Source, 1960-74



[1] GNP implicit price deflators used to convert current dollars to constant 1967 dollars.
[2] Includes state and local government sources.
SOURCE: National Science Foundation.

the 1960-74 period, although the annual increments were smaller after the late 1960's—the same years in which inflation grew fastest. As a result of these trends, funding by all sources except nonprofit institutions declined in constant dollars with the largest absolute reductions occurring in Federal Government support. Funds from this source in 1974 were down 16 percent in comparison with the peak funding year of 1968. Funds supplied by universities[5] continued to outpace inflation through 1972, but declined more than 13 percent between then and 1974. Industry's funding for basic research peaked in 1966 in constant dollars, then fluctuated around a somewhat lower level through 1974. Universities, on the other hand, raised their share of support from 6 percent in 1960 to 11 percent by 1974. Federal support, as a percentage of the total national expenditures, increased from 59 percent in 1960 to a high of 72 percent in 1967 before declining to 68 percent of the total in 1974.

Federal support of basic research

The Federal Government assumed prime responsibility for support of basic research after World War II. This policy recognized the decisive role played by scientific knowledge in the war effort, and sought to strengthen the Nation's basic research capability for peacetime pursuits. Over the past 30 years, the policy has come to be predicated on the broad and varied role of basic research in advancing the country's defense, economy, health, and technology, as well as upon its general cultural value, in education and in the intellectual life of the Nation. During this period, many Federal agencies came to support basic research as an instrument in fulfilling their missions, and a new agency—the National Science Foundation—was created for the express purpose of supporting scientific research and strengthening such capability.

Six of these agencies accounted for 95 percent of all Federal obligations[6] for basic research in Fiscal Year 1974.[7]

Percent of total Federal obligations for basic research, by agency, 1974

Federal agency	Percent basic
National Aeronautics and Space Administration (NASA)[8]	29
Department of Health, Education, and Welfare (HEW)	23
National Science Foundation (NSF)	16
Atomic Energy Commission (AEC)	11
Department of Defense (DOD)	10
Department of Agriculture (USDA)	6

Basic research and total R&D. Basic research funded by each of these Federal agencies, and performed intramurally or by other sectors, is a part of the overall R&D effort of that agency. The magnitude of the basic research component, in relationship of the total R&D program, suggests the relative importance assigned to basic research by the agency. This ratio is shown in figure 3-4 for each of the six agencies.

For all agencies as a whole, the ratio has increased slowly, reaching 15 percent of all R&D obligations in 1974. Obligations for basic research increased 20 percent between 1971-74, compared with a 14 percent increase for all R&D obligations.

The NSF has the largest ratio by far, as would be expected in view of its designated role in the support of basic research. Recent declines in this agency's concentration on basic research—down from just over 90 percent of its total R&D obligations in the mid-1960's to approximately 80 percent in 1974—are due to initiation of such new and largely applied research programs as "Research Applied to National Needs."

Two other agencies—NASA and HEW—show sizable changes in recent years in the fraction of their total R&D expenditures which is directed to basic research. The fraction for NASA has

[5] Includes funds from State and local governments, as well as the universities and colleges themselves.

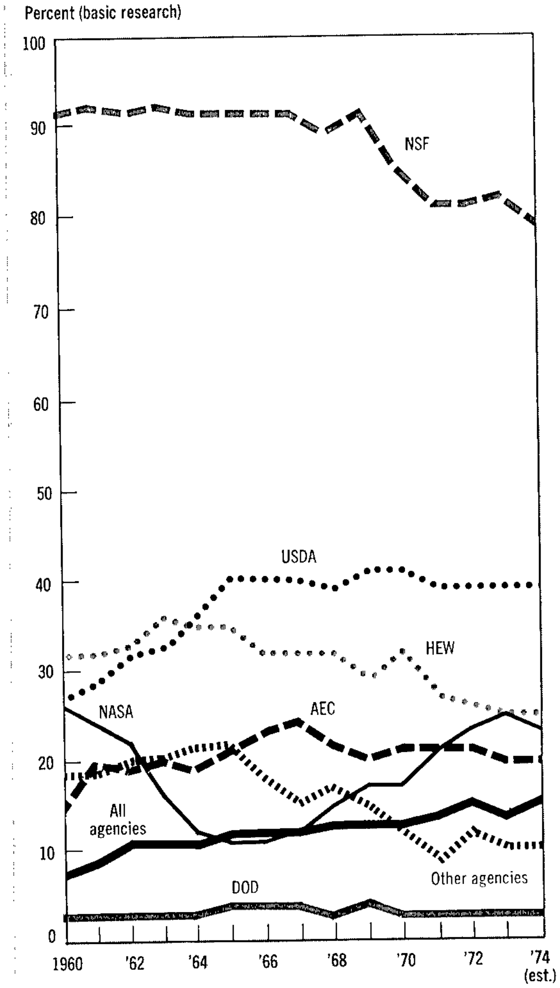
[6] Federal obligations for basic research may differ from federally provided expenditures in the same year for a number of reasons. A sector which performs research, for example, may report expenditures for research projects which it regards as "basic research," whereas the Federal agency providing the support may report the same projects as consisting of "applied research." In addition, obligations made in a given year may actually extend over several later years in terms of the availability of the funds for expenditure. Moreover, the withholding of obligated funds may produce discrepancies between obligations and reported expenditures.

[7] *Federal Funds for Research, Development, and Other Scientific Activities, Fiscal Years 1973, 1974 and 1975*, Vol. XXIII, National Science Foundation (NSF 74-320-A).

[8] NASA considers all of its activities to be R&D, or in support of R&D. The agency's obligations for basic research (as well as for applied research and development) include the related costs of spacecraft, launch vehicles, tracking and data acquisition, and the *pro rata* costs of ground operations and agency administration.

Figure 3-4

Federal Obligations for Basic Research as a Percent of Each Agency's R&D Obligations, by Agency, 1960-74



SOURCE: National Science Foundation.

ranged from a low of 11 percent in the mid-1960's to some 25 percent in the 1972-74 period, with much of the latter growth coinciding with reduced obligations for the manned-space program. Basic research obligations by HEW show a long-term decline, as a percentage of the agency's obligations for all R&D; increase in life sciences research "targeted" toward specific disease areas accounts in part for the declining fraction of basic research obligated in recent years by this agency.

Basic research obligations. Obligations for basic research alone are shown in figure 3-5 for each of the six agencies, as well as for all other agencies combined. Current dollar obligations were higher in 1974 than 1973 in each of the six agencies other than DOD and NASA. In contrast, constant dollar obligations declined in all agencies other than HEW.

The principal scientific disciplines supported by each of these agencies[9] and the agency missions which generated the need for basic research in 1974 were:

NASA. The physical and environmental sciences receive some 75 percent of all NASA's basic research obligations, primarily in connection with lunar and space exploration.

HEW. Some 80 percent of HEW's obligations for basic research are directed to the life sciences, principally for biomedical research, and almost 6 percent to the social sciences for research in areas such as education and drug abuse.

NSF. Over 30 percent of this agency's basic research obligations are for the physical sciences, with 23 percent for the environmental sciences, 16 percent for the life sciences, and 11 percent for engineering. The broad purpose of the research is to advance the state of basic scientific knowledge.

AEC. The physical sciences receive almost 80 percent of AEC's basic research obligations and the life sciences nearly 13 percent—principally in high energy physics and in nuclear sciences. The purpose of this research is to generate the foundation for the development and utilization of atomic energy.

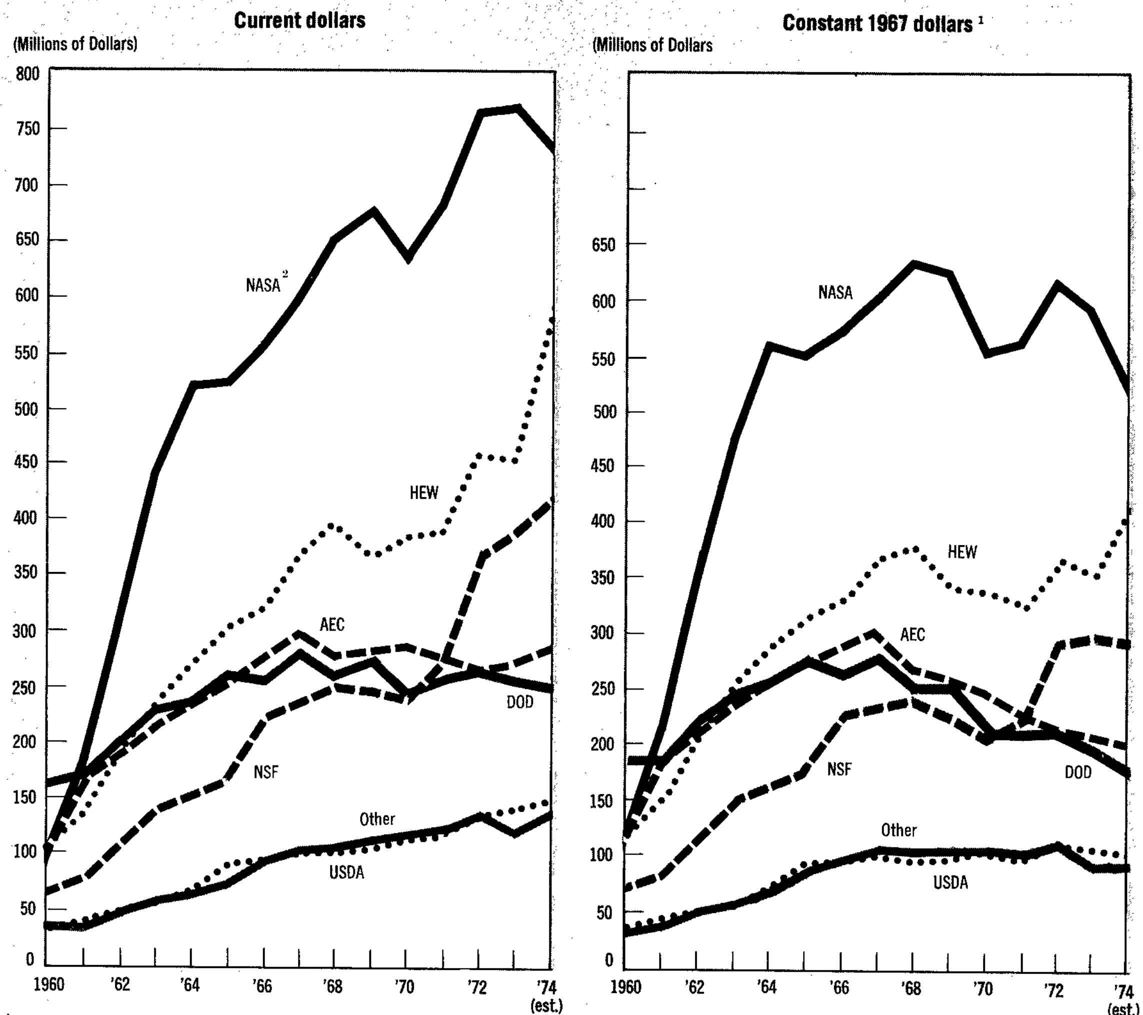
DOD. Engineering accounts for 29 percent of DOD's obligations for basic research, physical and environmental sciences 22 percent each, and the life sciences about 12 percent. The prime aim of the research is to provide the fundamental knowledge needed for developing future military systems and improved operations.

USDA. The life sciences receive some 70 percent and the physical sciences nearly 15

[9] *Federal Funds for Research, Development, and Other Scientific Activities, Fiscal Years 1973, 1974 and 1975*, Vol. XXIII, National Science Foundation (NSF 74-320-A).

Figure 3-5

Federal Obligations for Basic Research, by Agency, 1960-74



[1] GNP implicit price deflators used to convert current dollars to constant 1967 dollars.

[2] The large amounts reported by NASA for basic research are due to the substantial cost of support equipment such as spacecraft and launch vehicles peculiar to space exploration, and the statistical proration of costs for tracking and data acquisition.

SOURCE: National Science Foundation.

percent of all USDA's basic research obligations, as a part of the agency's R&D aimed at improving animal and plant productivity and enhancing the use of natural resources related to agriculture.

The proportion of total Federal obligations for basic research provided by each of these agencies shifted considerably in the period 1960-74. The Department of Defense provided 28 percent of the total basic research obligations in 1960, compared to 10 percent in 1974. This decline may be due, in part, to the "Mansfield amendment" which restricted the DOD to the funding of research related directly to its mission. The proportion supplied by NASA declined from a high of 33 percent in 1964 to 29 percent in 1974, reflecting both changes in the mission of this agency and the faster growth of basic research obligations in some other agencies.

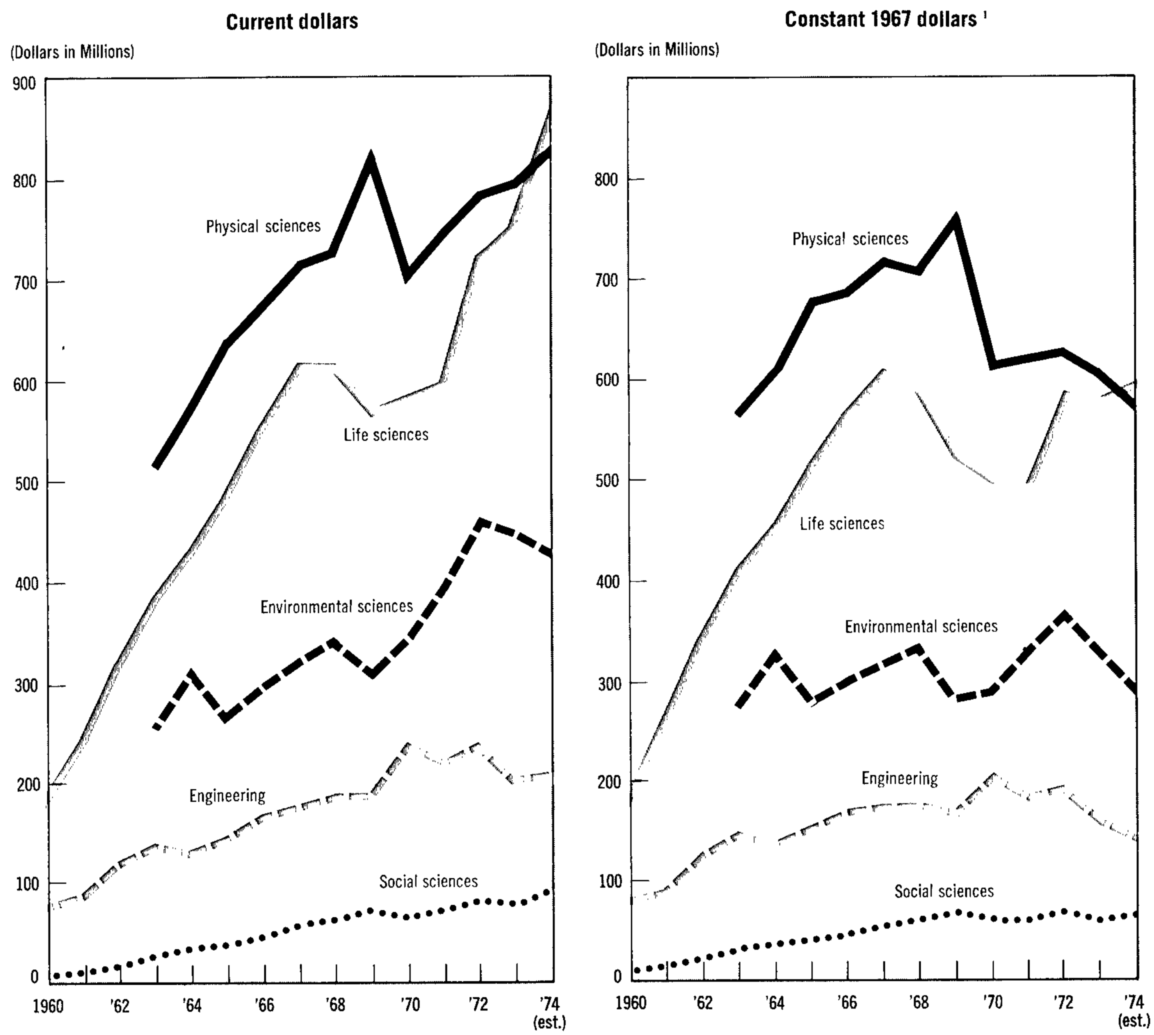
Accompanying the declines in DOD and NASA were recent increases in the fractions provided by HEW and NSF, with the former accounting for 23 percent of total obligations in 1974 (versus 17 percent in 1960), and the latter 16 percent (versus 11 percent in 1960). Much of the growth in HEW's share during the period occurred in 1973 and 1974 in connection with increased funding for cancer research; similarly, a large part of the growth in NSF's share took place in the years after 1970, as a result of increasing obligations for basic research in virtually all major scientific disciplines.

Basic research obligations in scientific areas. An overview of the distribution of Federal support for basic research by scientific area is presented in figure 3-6.[10] The five broad areas shown in the figure accounted for 95 percent of

[10] See Appendix table 3-6 for disaggregated data for certain disciplines and Appendix table 3-6a for a listing of the scientific disciplines encompassed in these broad fields.

Figure 3-6

Federal Obligations for Basic Research, by Selected Fields of Science, 1960-74



[1] GNP implicit price deflators used to convert current dollars to constant 1967 dollars.
SOURCE: National Science Foundation.

Federal obligations for basic research in Fiscal Year 1974. Three of the areas—life, physical, and social sciences—had reached their highest level of current dollar obligations in 1974, whereas obligations for the environmental sciences and engineering declined after 1972. In constant dollars, basic research obligations for all areas other than the life sciences were lower in 1974 than in some previous year. The largest decline occurred in the physical sciences, where constant dollar obligations decreased by 24 percent between 1969 and 1974.

A major and rapid shift in the distribution of basic research obligations among these areas of science occurred in the life and physical sciences. The proportion of obligations for the life sciences increased from 27 percent of the total obligations in 1969 to 34 percent in 1974. Over the same period, the fraction of total basic research obligations for the physical sciences dropped from 39 percent in 1969 to 32 percent in 1974. This shift from the physical to the life sciences is due to reductions or relatively slow growth in basic research obligations from DOD, NASA, and the AEC—the major sources of funding for the physical sciences—coupled with substantial increases in HEW's obligations for the life sciences (figure 3-5).

Within these broad areas, large changes have occurred in individual fields in recent years (Appendix table 3-6). In the area of physical sciences, for example, Federal obligations for basic research in physics were at their highest level in 1967 in constant dollars before declining 28 percent by 1974 when obligations were approximately at a pre-1963 level. In the life sciences, basic research obligations for the biological sciences grew steadily, whereas clinical medical sciences declined 58 percent in constant dollars between the peak funding year of 1967 and 1974.

BASIC RESEARCH IN UNIVERSITIES AND COLLEGES

Universities and colleges perform the bulk of the Nation's basic research. They accounted for 54 percent of the total national expenditures for such research in 1974 (figure 3-2). The presently dominant position of these institutions in fundamental research is the culmination of a long-term trend. In 1953, universities and colleges accounted for only 26 percent of the total expenditures for basic research, compared with 35 percent for industry and 24 percent for intramural research by the Federal Government. As funding of basic research rose over the years—primarily as the result of increasing Federal support—the fraction of the total going to universities and colleges grew rapidly, much more rapidly than funding in the industry and Federal intramural sectors. In consequence, the percentage of the total funds for basic research accounted for by these two sectors had declined to 16 percent each in 1974. There was little change in the share of basic research expenditures accounted for by the nonprofit institutions and the university FFRDC's, with each accounting for some 7 percent of basic research expenditures throughout the last decade (Appendix table 3-2).

The significant role of universities and colleges in basic research is reflected also in the fact that scientists and engineers employed by these institutions are responsible for a large proportion of all U.S. scientific research reports—approximately three-fourths of the total in 1973 (Appendix table 3-21). The research performed by these institutions, moreover, is increasingly the basis for advances in technology (figure 3-25).

Basic research in universities and colleges ranges from the efforts of individual scientists and engineers to those of large research teams which often are organized around the use of unique equipment and facilities. Most of the research takes place in universities which have graduate-level programs offering doctorate degrees; these institutions reported 98 percent of all academic basic research expenditures in 1974.[11] This concentration reflects, in part, the close relationship between research and graduate education in science and engineering. Research is an integral part of graduate education in these areas and, indeed, students are involved in performing much of the research. Graduate students in chemistry, for example, were coauthors of 56 percent of the research reports published in 1971 by institutions awarding doctorate degrees in that field.[12]

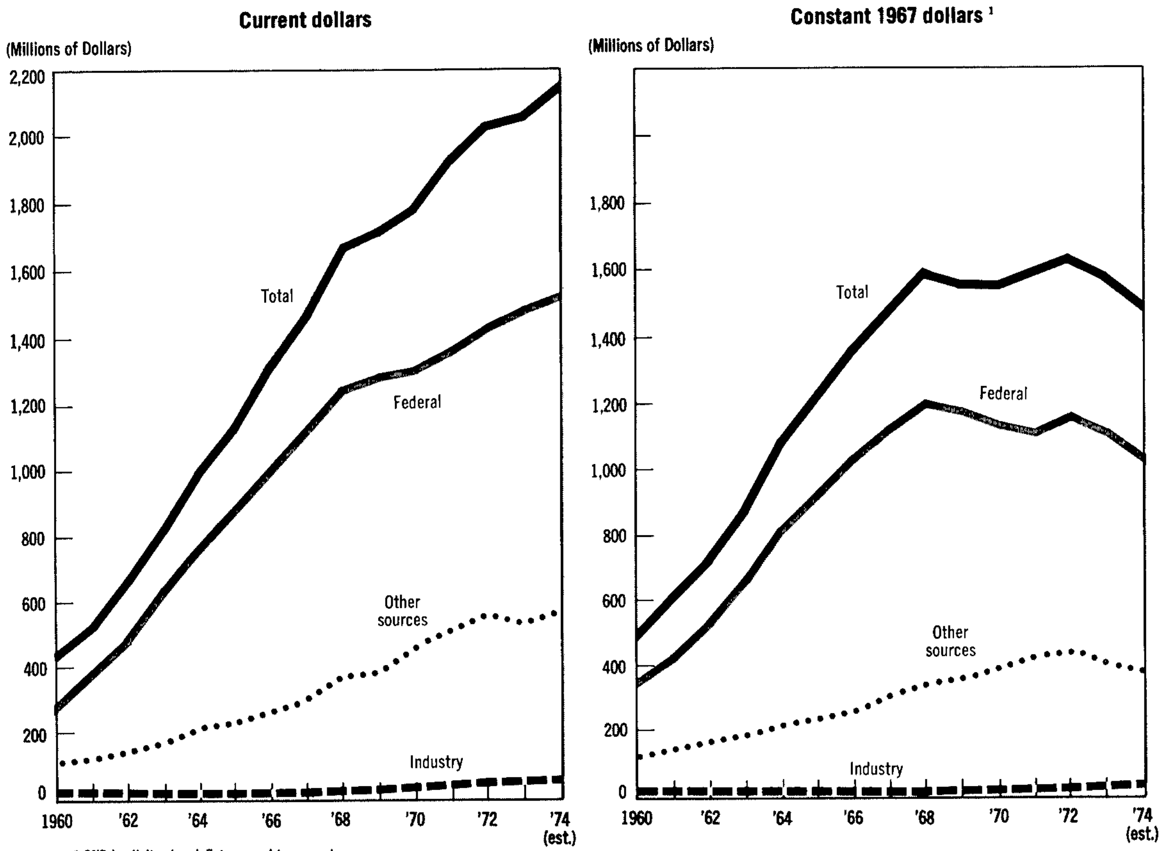
Expenditures by universities and colleges for basic research (from all funding sources combined) increased continuously from 1960 to 1974

[11] *Expenditures for Scientific and Engineering Activities at Universities and Colleges, FY 1973*, National Science Foundation (NSF 75-316-A).

[12] *Directory of Graduate Research*, American Chemical Society, 1971.

Figure 3-7

Basic Research Expenditures in Universities and Colleges, by Source, 1960-74



[1] GNP implicit price deflators used to convert current dollars to constant 1967 dollars.
SOURCE: National Science Foundation.

in current dollars, although the annual rate of growth diminished after 1968 (figure 3-7).[13] This decline in the growth rate, coupled with rising inflation, produced a level of constant dollar expenditures which changed little during the 1968-72 period. Small constant dollar increases in 1971 and 1972 were succeeded by larger decreases in the two following years, with the result that basic research expenditures in 1974 were 9 percent lower than in 1972, the year of highest constant dollar funding.

[13] These expenditure data are for R&D which has been sponsored by other agencies and organizations, as well as R&D supported by an institution's own funds which it allocates to separately organized institutes, divisions, or specific R&D projects. They do not include the expenditures for research/teaching assignments of the faculty (departmental research). Expenditures associated with FFRDC's administered by universities are treated later in this chapter.

The leveling off and decline in constant dollar expenditures for basic research is due mainly to reduced growth of funding by the Federal Government (figure 3-7), in combination with inflation. The scientific fields most affected by these declines were the physical sciences (particularly physics) and clinical medicine (see figure 3-9 and Appendix table 3-9).

Sources of funds for basic research

The sources of financial support for basic research in universities and colleges are shown in figure 3-7. The largest of these—the Federal Government—provided substantial annual increases in current dollars between 1960-68, but reduced significantly the average annual increments in later years. Translated to constant

dollars, Federal funding for basic research reached a maximum in 1968 and declined a total of 13 percent by 1974. In spite of the slowed growth in current dollars, the Federal Government provided 70 percent of all funds expended by the academic sector for basic research in 1974—down, however, from the high of 77 percent which prevailed between 1964-67.

Funds provided by "All other sources"[14] for basic research in figure 3-7 increased in both current and constant dollars until 1972—thus replacing some of the reduced Federal support—before declining 11 percent in constant dollars by 1974. These sources of support accounted for 27 percent of the total support for basic research in these institutions in 1974.

Basic research in fields of science

Estimates of total academic expenditures for basic research in selected fields of science are presented in figure 3-8.[15] These estimates are based upon a survey conducted by the National Science Foundation in which universities and colleges report their total research and development expenditures for each of several fields of science, as well as the percentages of the total R&D expenditures (over all fields combined) which are given to basic research, applied research, and development. This information is correlated with other factors—such as the source of the research support and the type of academic institution which performed the research—in deriving the estimates of expenditures for basic research in the individual scientific fields. Because these data are estimates, and may differ from actual expenditures, they should be regarded only as approximations.[16]

The six broad areas of scientific research indicated in figure 3-8 received almost 90 percent of all expenditures for basic research in universities and colleges in 1974.[15] Expenditures for fundamental research in these institutions are concentrated in the life science fields of clinical medicine and the biological sciences; 51 percent of all basic research expenditures in 1974 was in these fields. About one-fourth of the total expenditures was divided almost equally between engineering and the physical sciences (principally physics and chemistry), while the social sciences received 8 percent and environmental sciences 7 percent of the total (Appendix table 3-8).

In current dollars, basic research expenditures increased between 1973 and 1974 in all areas except engineering. In constant dollars, however, a reduction in basic research spending was recorded in all fields other than the environmental sciences and clinical medicine, with the largest declines occurring in engineering and the biological sciences.

Federal Government support of basic research

Current dollar expenditures from Federal Government sources for basic research in universities and colleges increased throughout most of the 1964-74 period for each of the six broad fields of science and engineering, except for a 14 percent decline in engineering expenditures from 1973 to 1974 (figure 3-9).[17] Increases in the level of support after 1968, however, were less than increases in inflation in all fields other than the environmental and biological sciences. As a result, the magnitude of the federally funded research effort—as measured by constant dollar expenditures—was lower in 1974 than in some previous year in each of the six fields. The fields with the largest reductions were engineering, the physical sciences, and clinical medicine, which recorded declines of 26, 30, and 10 percent, respectively, between 1968 and 1974 (see Appendix table 3-9).

The Federal Government, as noted earlier, provided 70 percent of all funds expended by universities and colleges for basic research in 1974. The dependence on this source of support, while varying from field to field, declined over the last decade in all fields other than the biological sciences, as shown below:

[14] This includes universities and colleges, State and local governments, and other nonprofit institutions.

[15] See Appendix table 3-8a for a listing of the scientific disciplines encompassed by these broad fields and Appendix table 3-8 for more detailed data for certain disciplines.

[16] The feasibility of obtaining data directly on basic research expenditures in individual fields of science is being investigated and may be attempted in future NSF surveys.

[17] These data are estimates based on the same NSF survey as the total expenditures for basic research in academic institutions presented in figure 3-8.

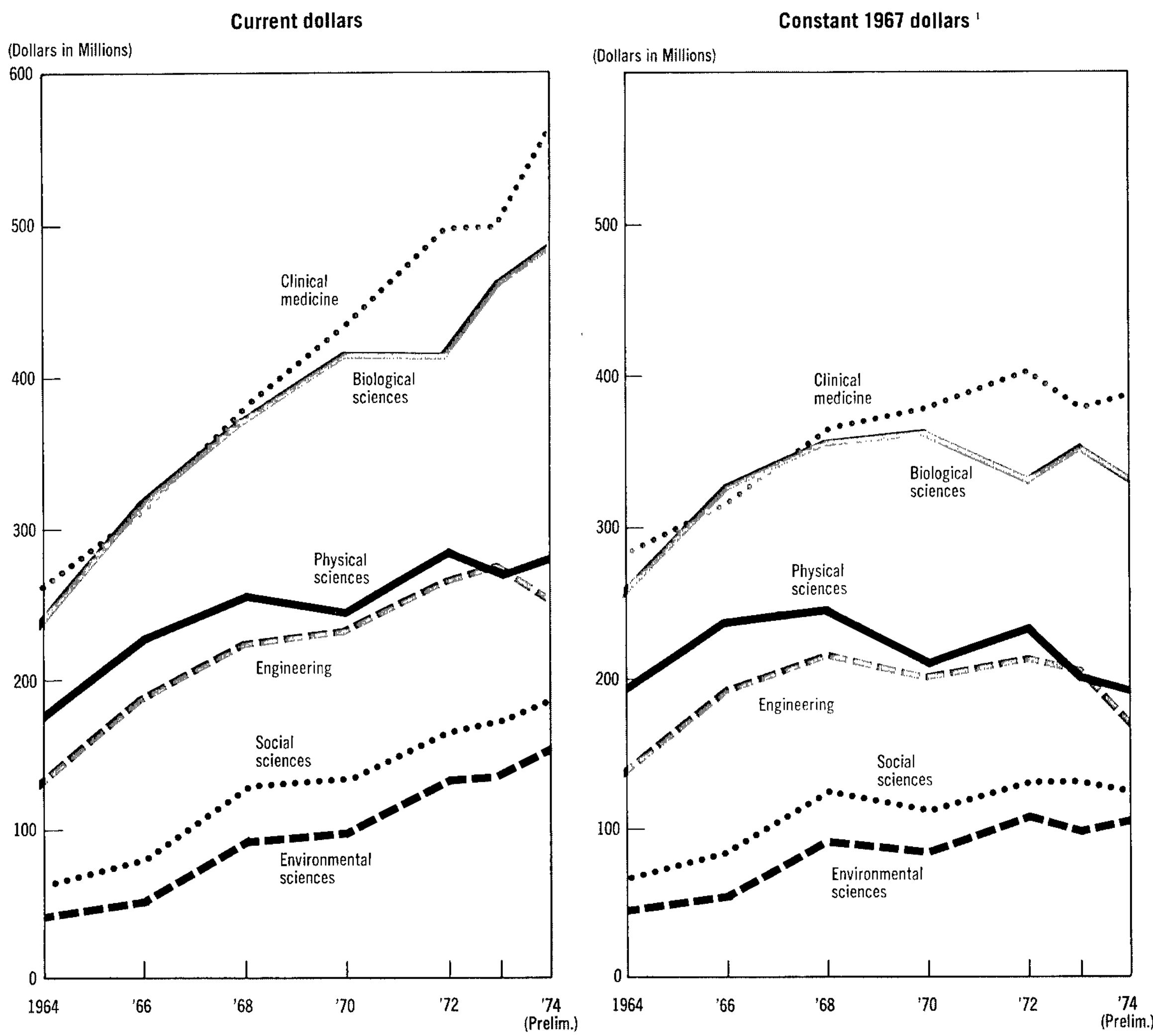
Selected fields	Federal support as a percent of all basic research expenditures 1964	1974
All fields	76	70
Physical sciences	93	82
Chemistry	89	78
Physics	97	87
Environmental sciences	91	74
Life sciences	69	69
Clinical medicine	84	77
Biological sciences	53	59
Engineering	82	69
Social sciences	61	58
Other fields	80	72

Support by Federal agencies. The six Federal agencies mentioned earlier accounted for 98 percent of total Federal obligations to universities and colleges for basic research in 1974, with the NSF and HEW alone providing 74 percent of all such obligations. The individual Federal agencies differ greatly in the proportion of their total obligations for basic research which they direct to universities and colleges.[18] Of the

[18] *Federal Funds for Research, Development, and Other Scientific Activities, Fiscal Years 1973, 1974 and 1975, Vol. XXIII* National Science Foundation (NSF 74-320-A), and earlier volumes in this report series.

Figure 3-8

Estimated Basic Research Expenditures in Universities and Colleges, by Field of Science, 1964-74



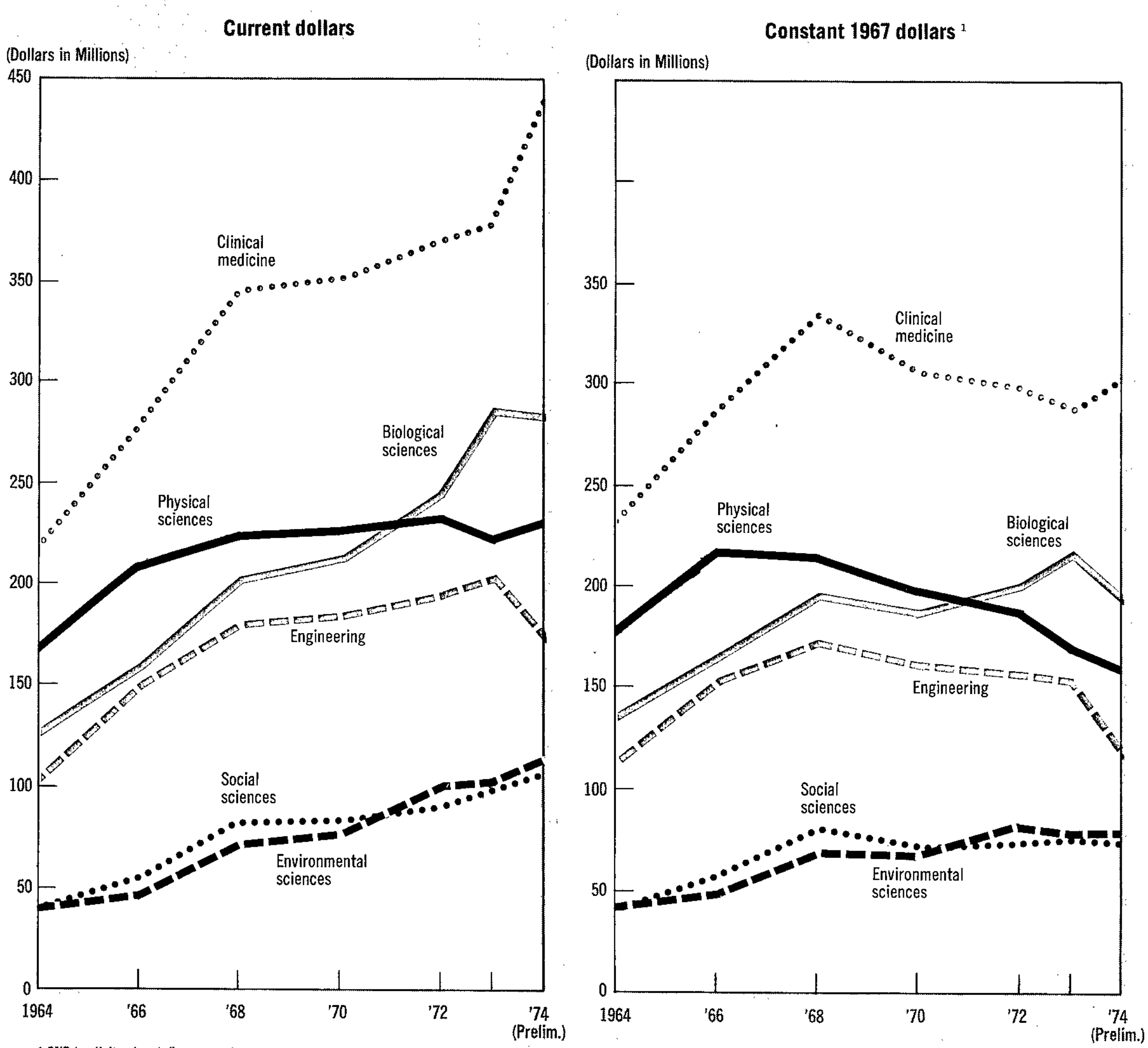
[1] GNP implicit price deflators used to convert current dollars to constant 1967 dollars.
SOURCE: National Science Foundation.

six agencies noted earlier, NSF and HEW allocated the largest fraction of their total basic research obligations to educational institutions in 1974 (84 and 70 percent, respectively), followed by DOD (44 percent), USDA (24 percent), AEC (21 percent), and NASA (6 percent).

Comparably large variations exist among the agencies in respect to the allocation of basic research obligations for broad fields of science and engineering at universities and colleges, as shown in the following table.

Figure 3-9

Estimated Federal Basic Research Expenditures in Universities and Colleges, by Field of Science, 1964-74



[1] GNP implicit price deflators used to convert current dollars to constant 1967 dollars.
SOURCE: National Science Foundation.

Percentage of total basic research obligations directed to universities and colleges, by field, 1974[19]

Fields of science[20]	NSF	HEW	DOD	USDA	AEC	NASA
Life sciences	83	73	30	24	29	3
Physical sciences	82	84	36	8	19	11
Environmental sciences	63	—	54	22	—	6
Engineering	97	92	40	12	25	12
Social sciences	90	37	—	56	—	—

These fields of science and engineering are supported by various combinations of Federal agencies, as indicated in figure 3-10 which presents the proportion of Federal obligations provided by each of the six agencies to universities and colleges for basic research in each major field. The figure indicates that either one or two agencies alone provided at least 70 percent of all Federal obligations for basic research in each field. The NSF and HEW together, for example, provided nearly 90 percent of all federally obligated dollars for basic research in the life sciences in 1974, almost 83 percent of the obligations for psychology and the social sciences, and approximately 75 percent for chemistry. Similarly, two agencies (DOD and NSF) accounted for more than 85 percent of the six agencies' obligations for the environmental sciences and some 80 percent of those for engineering, while the AEC and NSF in combination provided nearly 80 percent of all obligations for physics research in universities and colleges.

The fact that the NSF in 1974 provided either the largest or next largest amount of basic research obligations in the several fields—and nearly 35 percent of all obligations from the six agencies—underscores the extent of dependency on that agency by universities and colleges for support of basic research.

Institutional concentration of basic research

Basic research is concentrated in institutions which award advanced degrees in science and engineering. The 280 universities which grant doctorate degrees in the sciences and engineering accounted for 98 percent of academic basic research expenditures in 1974, with 82 percent of the total expenditures concentrated in 100 such institutions.[21] Little change occurred in this pattern of institutional concentration during the 1964-74 period as shown in the table below, although there were considerable shifts in the positions of specific institutions.

Percentage of expenditures for basic research by groups of institutions ranked in order of expenditures, 1964 and 1974

Year	First 10	First 20	First 40	First 60	First 80	First 100
1964	25	41	60	72	NA	NA
1974	24	39	59	72	81	86

The institutional concentration of R&D expenditures varies among the five broad scientific areas (figure 3-11).[22] The life sciences exhibited the least concentration in 1974, and the environmental sciences the greatest. The social sciences, physical sciences, and engineering had similar patterns of distribution or concentration, although varying considerably among individual institutions. The ten academic institutions with the largest R&D expenditures in the life sciences, for example, reported 23 percent of the total for all universities in 1974, compared with a concentration of 47 percent of all environmental science R&D expenditures in the first ten institutions for that field. No university ranked among the first ten in all five fields, and only one university held this position in four of the fields—reflecting a diversity of field concentration patterns even within the major research universities.

[19] *Ibid.*, and special tabulations.

[20] See Appendix table 3-6a for descriptions of these fields.

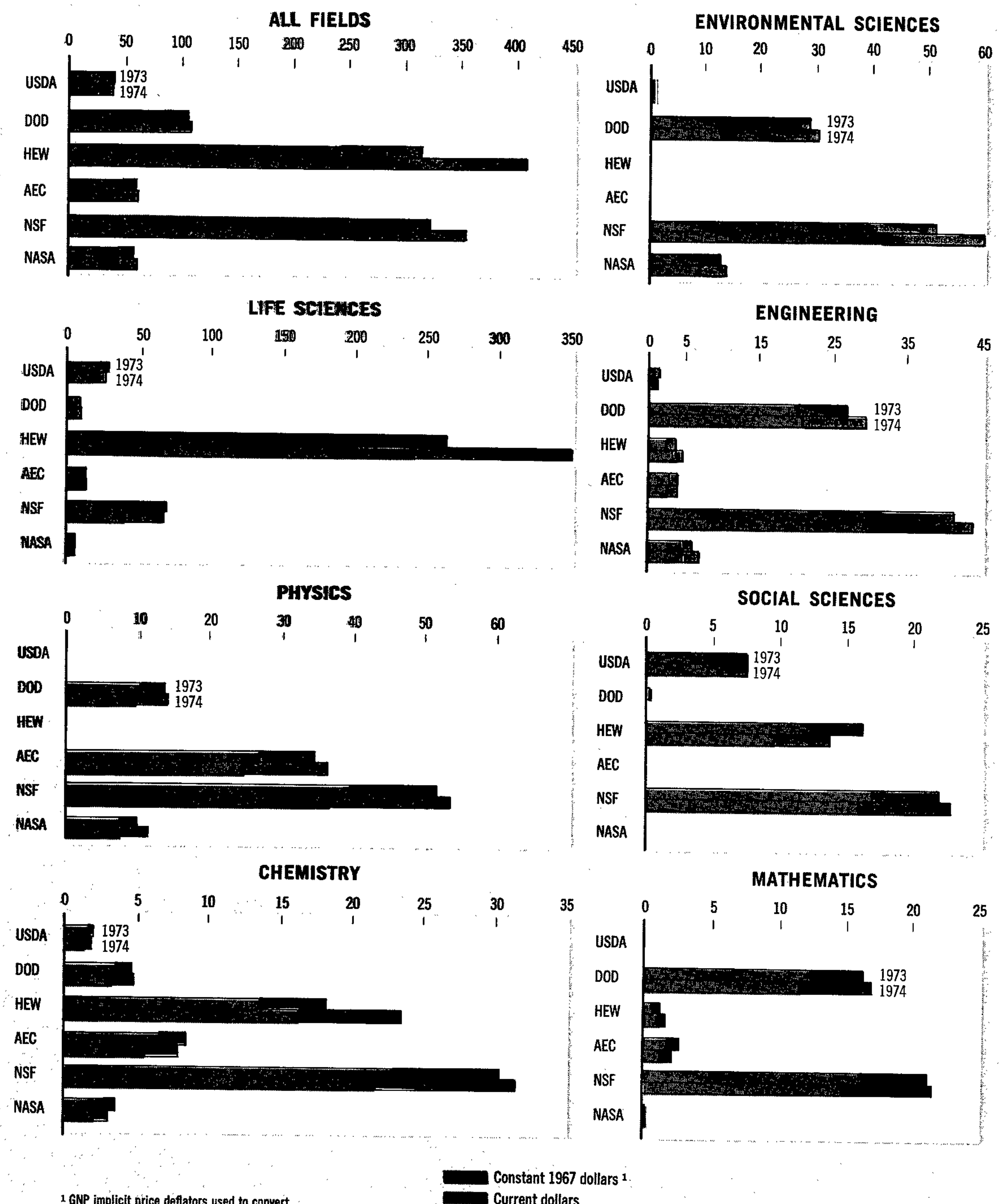
[21] *Expenditures for Scientific and Engineering Activities at Universities and Colleges, FY 1973*, National Science Foundation (NSF 75-316-A), and special tabulations.

[22] Data on basic research expenditures alone are not available for separate fields of science and individual institutions. An approximation is available, however, in the form of total R&D expenditures by these institutions in scientific fields, the largest component of which is basic research.

Figure 3-10

Federal Obligations for Basic Research in Universities and Colleges, by Selected Supporting Agencies and by Selected Fields, 1973-74

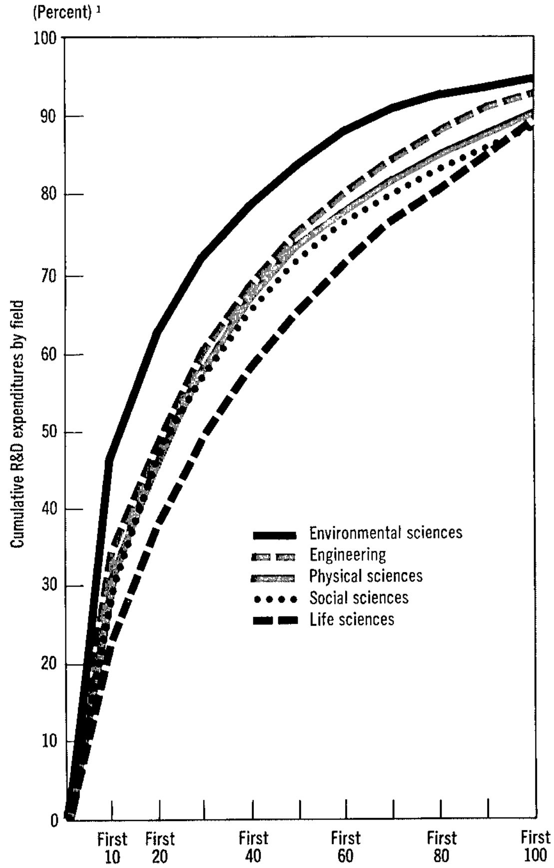
(Dollars in Millions)



[1] GNP implicit price deflators used to convert current dollars to constant 1967 dollars.
SOURCE: National Science Foundation.

Figure 3-11

Concentration of R&D Expenditures at the 100 Universities and Colleges with the Greatest Expenditures in Selected Fields, 1974



[1] Based on total R&D expenditures in individual fields.

SOURCE: National Science Foundation.

Basic research expenditures per scientist and engineer

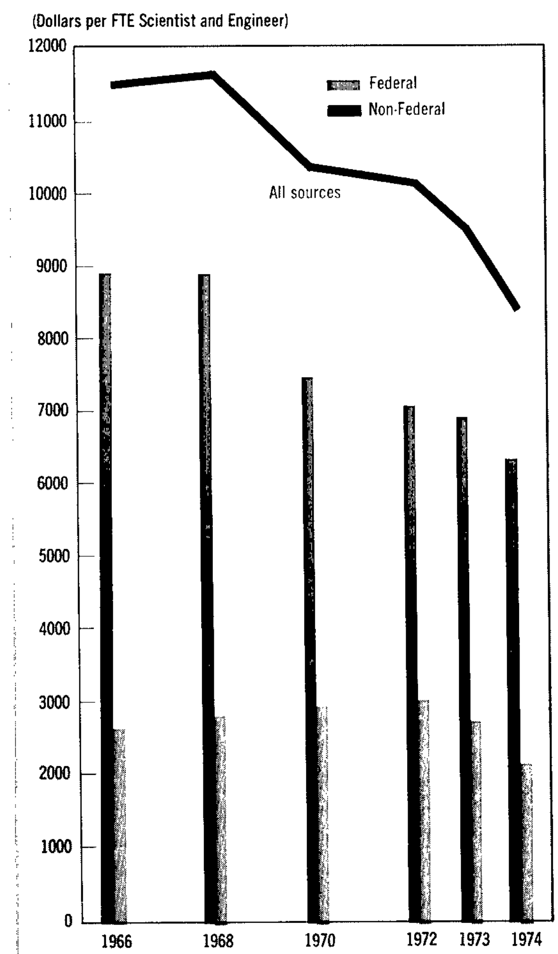
Basic research expenditures in doctorate institutions[23] reached their highest level in 1972 in constant dollars and then dropped nearly 15 percent over the next two years (see Appendix table 3-12), while the number of scientists and engineers in these institutions rose continuously through 1974. This increase of scientists and engineers was due partially to an expanding number of institutions awarding doctorate degrees in a science or engineering field—224 such universities in 1969 compared with 280 in 1974—as well as increases in the number of such personnel at existing doctorate-level institutions.

These trends—an increase in the number of scientists and engineers and a drop in real expenditures for basic research—have produced a reduction of almost 30 percent in constant dollar expenditures per scientist and engineer in

Figure 3-12

Basic Research Expenditures per Scientist and Engineer[1], in Doctorate-granting Institutions, by Source, 1966-74

(in constant 1967 dollars [2])



[1] Full-time-equivalent basis.

[2] GNP implicit price deflators used to convert current dollars to constant 1967 dollars.

SOURCE: National Science Foundation.

[23] Those granting doctorates in at least one science or engineering field.

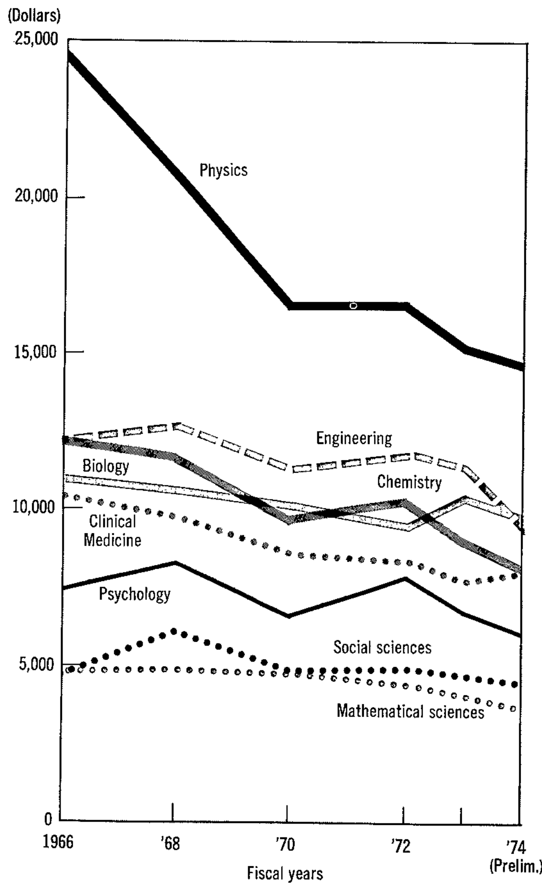
doctorate institutions since 1968 (figure 3-12). A slight shift from expenditures for basic to applied research occurred after 1972 and is one reason for this decline, the inclusion of scientists and engineers from the new doctorate institutions is another, and the reduction in constant dollar expenditures, particularly those supported by the Federal Government, is a third factor. Federal funds for basic research per scientist and engineer declined almost 30 percent between 1968 and 1974. Funds from other sources decreased by a similar percentage after 1972, but the reduction in absolute terms was much less than the Federal declines.

The reductions in real expenditures for basic research per scientist and engineer have occurred in several fields,[24] as shown in figure 3-13. The largest decline was recorded in physics, where such expenditures dropped almost 40 percent between 1966 and 1974. Decreases in this field were due primarily to declines in funding, rather than to increases in the number of physicists.

Figure 3-13

Estimated Basic Research Expenditures in Doctorate-granting Institutions per Scientist or Engineer[1] by Selected Fields, 1966-74

(in constant 1967 dollars)[2]



[1] Full-time equivalent basis.
[2] GNP implicit price deflators used to convert current dollars to constant 1967 dollars.
SOURCE: National Science Foundation.

BASIC RESEARCH IN FEDERALLY FUNDED RESEARCH AND DEVELOPMENT CENTERS ADMINISTERED BY UNIVERSITIES

Federally Funded Research and Development Centers (FFRDC's) are organizations financed exclusively or primarily by the Federal Government to perform R&D in relatively specific areas, or in some instances to provide facilities at universities for research and associated training purposes. The Centers usually have a direct and long-term relationship with their funding agency, making it possible for them to maintain instrumentation, facilities, and operational support beyond the capabilities of single educational or research institutions. Non-Federal organizations—academic, industrial, or nonprofit—administer the FFRDC's.

In 1974, FFRDC's administered by universities accounted for 7 percent of the Nation's total basic research expenditures,[25] and 86 percent of the Federal obligations for all FFRDC's.[26] These Centers and their sponsoring agencies are:

Atomic Energy Commission

Ames Laboratory
Argonne National Laboratory
Brookhaven National Laboratory

[24] The actual cost of conducting research differs substantially from field to field, reflecting in part the extent to which research depends upon special equipment, facilities, and technical support staff.

[25] *National Patterns of R&D Resources, 1953-75*, National Science Foundation, (NSF 75-307).

[26] *Federal Funds for Research, Development, and Other Scientific Activities, Fiscal Years 1973, 1974 and 1975*, Vol. XXIII, National Science Foundation (NSF 74-320-A).

Cambridge Electron Accelerator
Fermi National Accelerator Laboratory
E.O. Lawrence Berkeley Laboratory
E.O. Lawrence Livermore Laboratory
Los Alamos Scientific Laboratory
Oak Ridge Associated Laboratory
Plasma Physics Laboratory
Stanford Linear Accelerator

Department of Defense

Applied Physics Laboratory
Applied Research Laboratory
Center for Naval Analyses
Lincoln Laboratory

National Aeronautics and Space Administration

Jet Propulsion Laboratory
Space Radiation Effects Laboratory

National Science Foundation

National Astronomy and Ionosphere Center
Cerro Tololo Inter-American Observatory
Kitt Peak National Observatory
National Center for Atmospheric Research
National Radio Astronomy Observatory

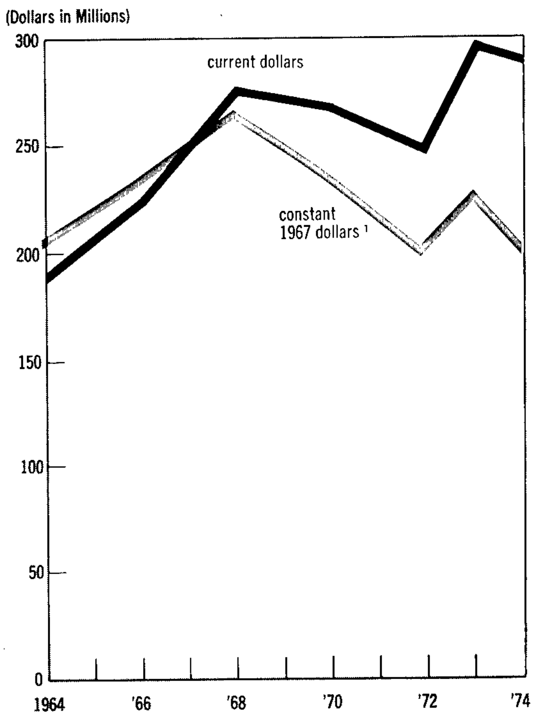
In current dollars, expenditures by university-managed FFRDC's for basic research were at their highest level in 1973 and declined slightly in 1974 (figure 3-14). In constant dollars, however, basic research expenditures in 1974 were almost 25 percent less than those of the 1968 peak year and approximately equal to expenditures in 1964. Data are not available on expenditures for specific scientific fields, but it is apparent from the above listing of the Centers, and the Federal agencies involved, that the basic research is predominantly in the physical sciences and engineering. The proportion of all R&D expenditures in FFRDC's reported as basic research has remained at nearly 35 percent in the last few years.[27]

Although some of the FFRDC's are permitted to receive support from sources other than the Federal Government, such funds amounted to less than 1 percent of their total funding in 1974.

[27] See Appendix table 3-14.

Figure 3-14

Basic Research Expenditures at Federally Funded Research and Development Centers Administered by Universities, 1964-74



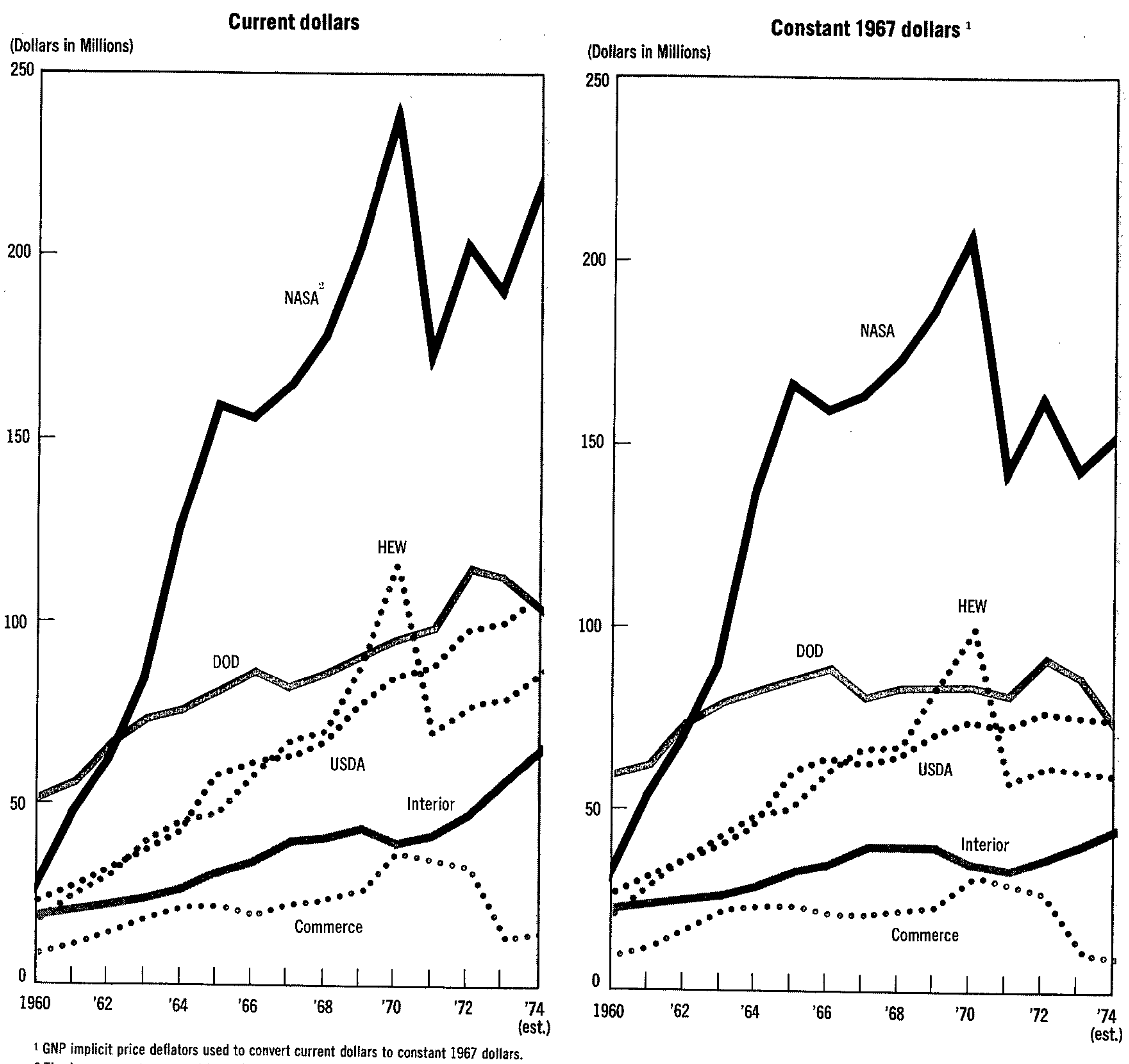
¹ GNP implicit price deflators used to convert current dollars to constant 1967 dollars.
SOURCE: National Science Foundation.

BASIC RESEARCH IN INTRAMURAL FEDERAL LABORATORIES

Several agencies of the Federal Government operate their own R&D laboratories as part of their effort to meet the research needs associated with their agency mission and program objectives. Intramural laboratories were responsible for 16 percent of the total basic research expenditures and 23 percent of all federally supported basic research in 1974. About 94 percent of all such research in 1974 was undertaken by the six agencies indicated in figure 3-15. Examples of such laboratories are the Goddard Space Flight Center of NASA, the National Animal Disease Laboratory of USDA,

Figure 3-15

Federal Obligations for Intramural Basic Research, by Selected Agencies, 1960-74



[1] GNP implicit price deflators used to convert current dollars to constant 1967 dollars.

[2] The large amounts reported by NASA for basic research are due to the substantial cost of support equipment such as spacecraft and launch vehicles peculiar to space exploration, and the statistical proration of costs for tracking and data acquisition.

SOURCE: National Science Foundation.

and the R&D Institute at the National Cancer Institute of HEW.[28]

Current dollar funding for basic research in these laboratories increased steadily from 1960 to 1970, and then after a slight decline in 1971 had risen again by 1974.[29] In constant dollars, however, 1974 funding was approximately equal to that of 1965, and down 22 percent from the peak year of 1970.

The constant dollar decline in intramural basic research funding is evident in all major agencies

[28] For further information on the utilization of intramural Federal laboratories see: U.S. Congress, House Committee on Appropriations, Agriculture-Environmental and Consumer Protection Appropriations for 1975; Part 7, *Investigative Report on the Utilization of Federal Laboratories* - 93rd Cong., 2nd Sess., 1974.

[29] See Appendix table 3-15.

except the Department of the Interior (figure 3-15). In the case of NASA, HEW, and Commerce, the year of highest funding of intramural basic research support was 1970, after which funding decreased in each of the agencies. By 1974, NASA's funding had declined more than 25 percent over its 1970 level, HEW by 40 percent, and Commerce by almost 70 percent. Basic research in DOD and USDA intramural laboratories received the highest level of constant dollar support in 1972. The DOD program declined by just over 20 percent while the USDA program remained fairly constant through 1974. In contrast, the Department of the Interior obligations for intramural basic research reached their highest level in 1974.

BASIC RESEARCH IN INDUSTRY[30]

Basic research consists of original investigations for the advancement of scientific knowledge which has no specified commercial objective, although the research may be within the general area of a company's interest. Such research, which is conducted largely by manufacturing industries, may provide a technical basis for product improvement, expansion or new business, and a defense against technological obsolescence.

Expenditures for basic research in industry represented 16 percent of the total national funds spent for basic research in 1974, but only 3 percent of all R&D expenditures in industry.[31] Although the current dollar total from all sources has risen, particularly since 1972, the effect of inflation has been to reduce the 1974 basic research expenditures in industry to approximately the same level as 1961 (figure 3-16). Federal support has dropped 12 percent since 1971 in constant dollars compared to a 3 percent increase of non-Federal basic research expenditures. The proportion of basic research in industry which has had Federal support has been about 22 percent for the last three years, compared to 32 percent in 1967.

Over three-fourths (78 percent) of the 1973 basic research expenditures in industry were accounted for by only four industries (figure 3-17): chemicals and allied products (37 percent), electronic equipment and communications (28 percent), aircraft and missiles (9 percent), and machinery (4 percent).

For the most part, basic research in industry is concentrated in the physical sciences and engineering (some 80 percent in 1973). Expenditures in the physical sciences, however, have declined significantly since the late 1960's, in both current and constant dollars (figure 3-18), while engineering expenditures reached their highest level in 1973 in current dollars. Constant dollar expenditures in the life sciences, on the other hand, grew substantially in the late 1960's before peaking in 1971 and then declining.

BASIC RESEARCH IN NONPROFIT INSTITUTIONS

Independent nonprofit institutions are organizations other than educational institutions chartered to serve the public interest, and include research institutes, hospitals, private foundations, science exhibitors, professional societies, trade associations, and FFRDC's administered by such nonprofit institutions. Although the largest single category is the research institutes, the others generally perform other services in addition to research, such as patient care or charitable activities.

These institutions were responsible for 7 percent of the Nation's expenditures for basic research in 1974, a fraction which changed little during the 1960-74 period. Current dollar expenditures for basic research in nonprofit institutions reached their maximum in 1974 (figure 3-19). In terms of constant dollar expenditures, funds for basic research in 1974 were comparable in magnitude to the funding level of earlier years (1971 and 1962-63), and approximately 20 percent lower than the year of highest funding which was 1966.

Federal sources provide the greatest part of support for basic research in these institutions and have a large impact on the total level of funding in any given year. In 1974, Federal support accounted for 53 percent of all basic research expenditures in nonprofit institutions, compared to 58 percent in 1966 and 50 percent in 1960. In contrast to the fluctuating Federal funding, support from other sources rose comparatively steadily, although slowly.

Over the 1960-74 period, basic research as a proportion of total research and development expenditures by these institutions declined from 38 percent to 22 percent.

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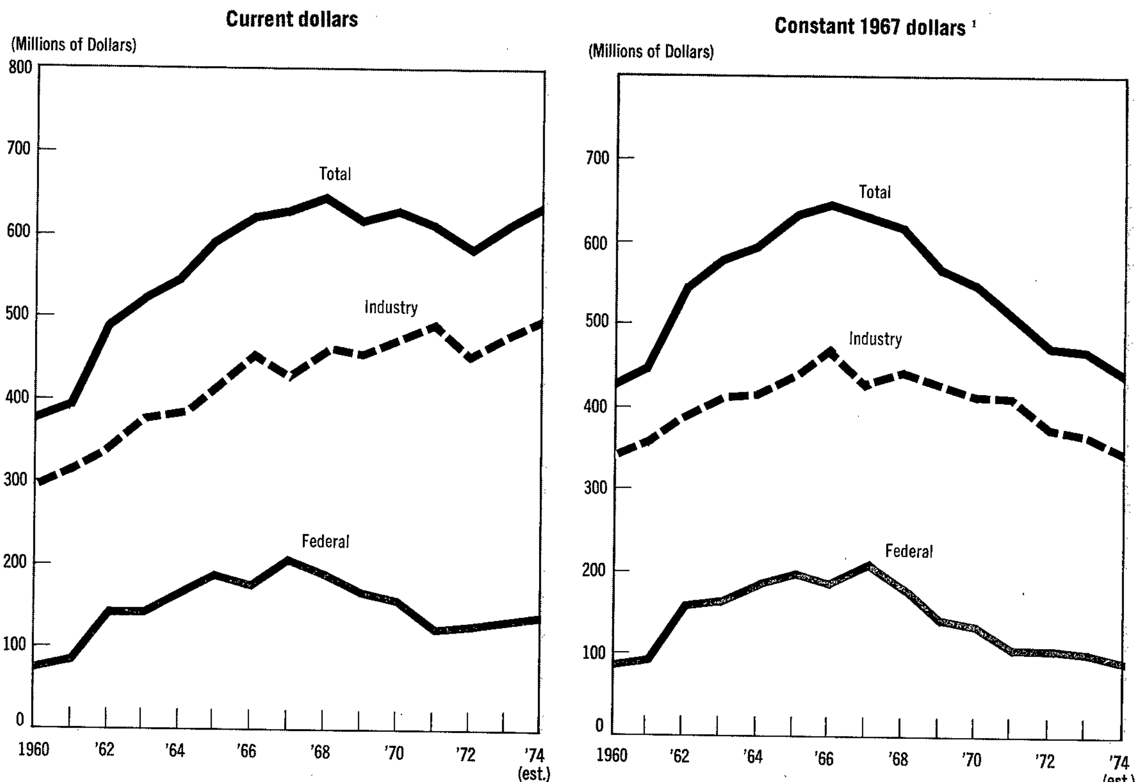
[30] A more comprehensive discussion of R&D in industry is found in a later chapter entitled, "Industrial R&D and Innovation."

[31] *National Patterns of R&D Resources, 1953-75*, National Science Foundation (NSF 75-307).

Figure 3-16

Industrial Basic Research Expenditures, by Source, 1960-74



[1] GNP implicit price deflators used to convert current dollars to constant 1967 dollars.
SOURCE: National Science Foundation.

RESEARCH OUTPUTS AND APPLICATIONS

Subsequent sections of this chapter present the results of experimental studies aimed at measuring a part of the output of research and a portion of its applications. The studies represent, at best, small steps in these directions.

Output of scientific research literature

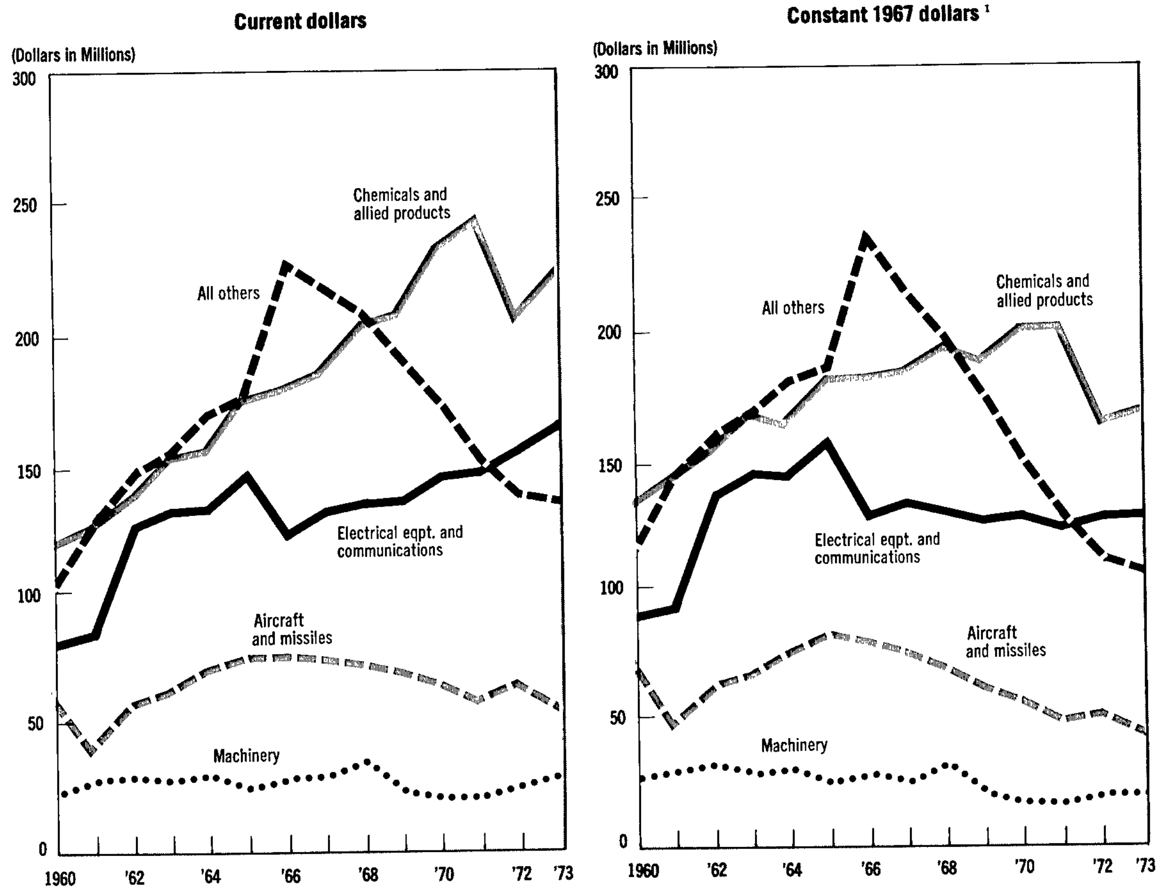
Information on the quantity and sectoral origin of published research reports from several fields of science was obtained from a study conducted by the National Federation of Abstracting and Indexing Services.[32] The study, in brief, involved the selection of a set of scientific and engineering journals which was representative of the total literature in each field. This was accomplished largely through the guidance of the Federation's member services and by advice from experts active in the fields. On a sampling basis, individual reports in the journals were examined to determine the first author's institutional affiliation: academic, government, industry, or other nonprofit organization. The sample of reports was restricted to those whose first authors were affiliated with U.S. institutions.

The data obtained from the study were used to develop preliminary measures of the relative growth of several fields of science and engineering in terms of their publication output, the roles of the different sectors in the overall research effort of each field, and the relationship between the research output and financial inputs.

[32] *Indicators of the Output of Scientific Research*, National Federation of Abstracting and Indexing Services, 1974 (A study commissioned specifically for this report, and funded largely by the Office of Science Information Service, National Science Foundation).

Figure 3-17

Expenditures for Basic Research in Industry, by Major Performing Industries, 1960-73



1 GNP implicit price deflators used to convert current dollars to constant 1967 dollars.
SOURCE: National Science Foundation.

Growth in research output. The extent and pattern of the relative growth in research publications are shown in figure 3-20 for each of 13 fields of science and engineering. The fields listed in this figure are presented in descending order with respect to the magnitude of their relative growth in publications during the 1960-73 period. The fields included in the top part of the figure grew by more than 200 percent during the period, those in the second plot by more than 100 but less than 200 percent, those in the third by more than 75 but less than 100 percent, and those in the bottom plot by less than 75 percent.

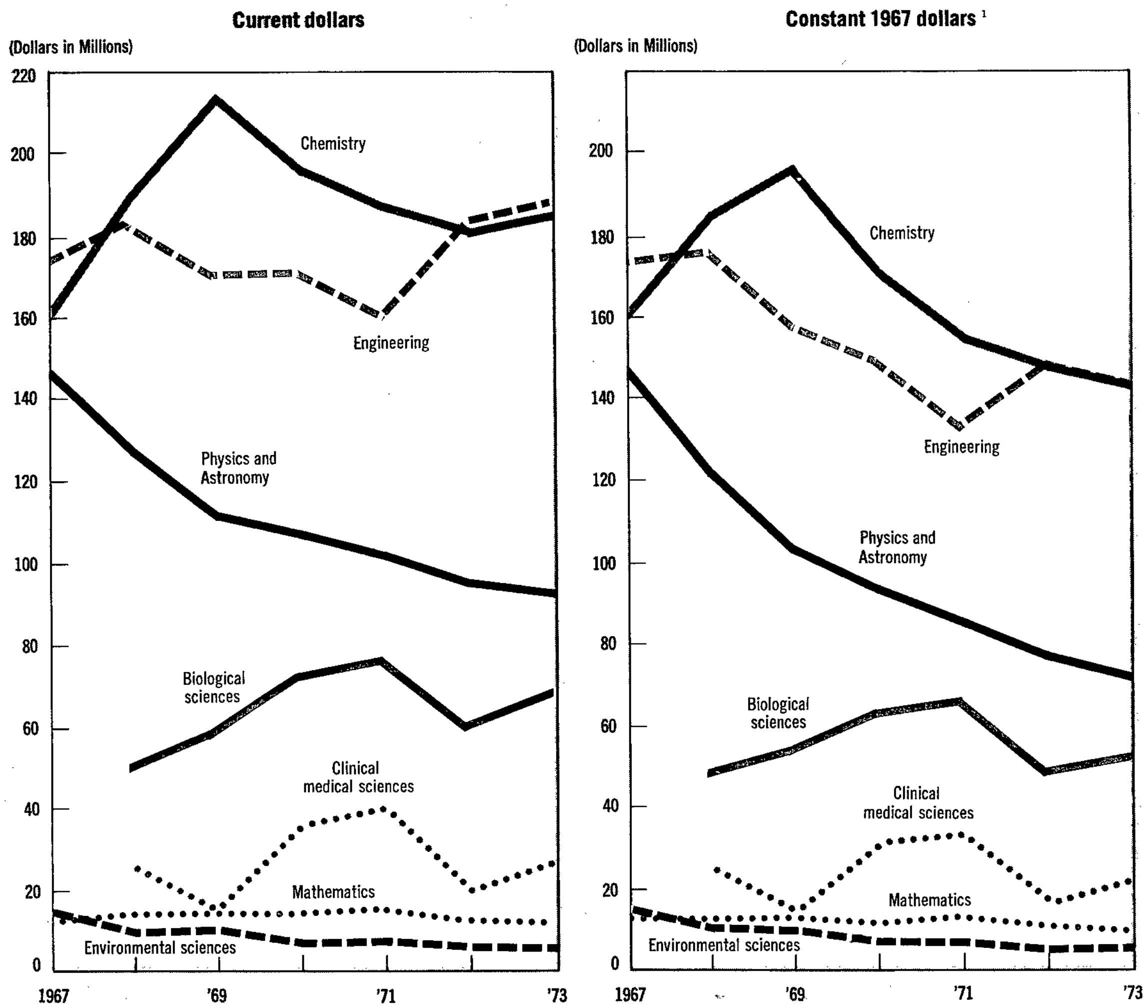
The fields differ considerably in their pattern of growth. For example, research publications in physics, chemistry, and engineering[33] (third plot from top) have remained at nearly a constant level since the late 1960's, whereas astronomy and biology (second plot from top) grew continuously throughout the period. The field of oceanography exhibits one of the more complex and unusual growth patterns; research publications in that field rose rapidly until 1969, but declined in most subsequent years.[34]

[33] These fields, as noted later in this chapter, play a large role in technological innovation.

[34] For information on the U.S. output of scientific research in an international context, see the chapter entitled, "International Indicators of Science and Technology" in this report.

Figure 3-18

Expenditures for Basic Research in Industry, by Selected Fields, 1967-73



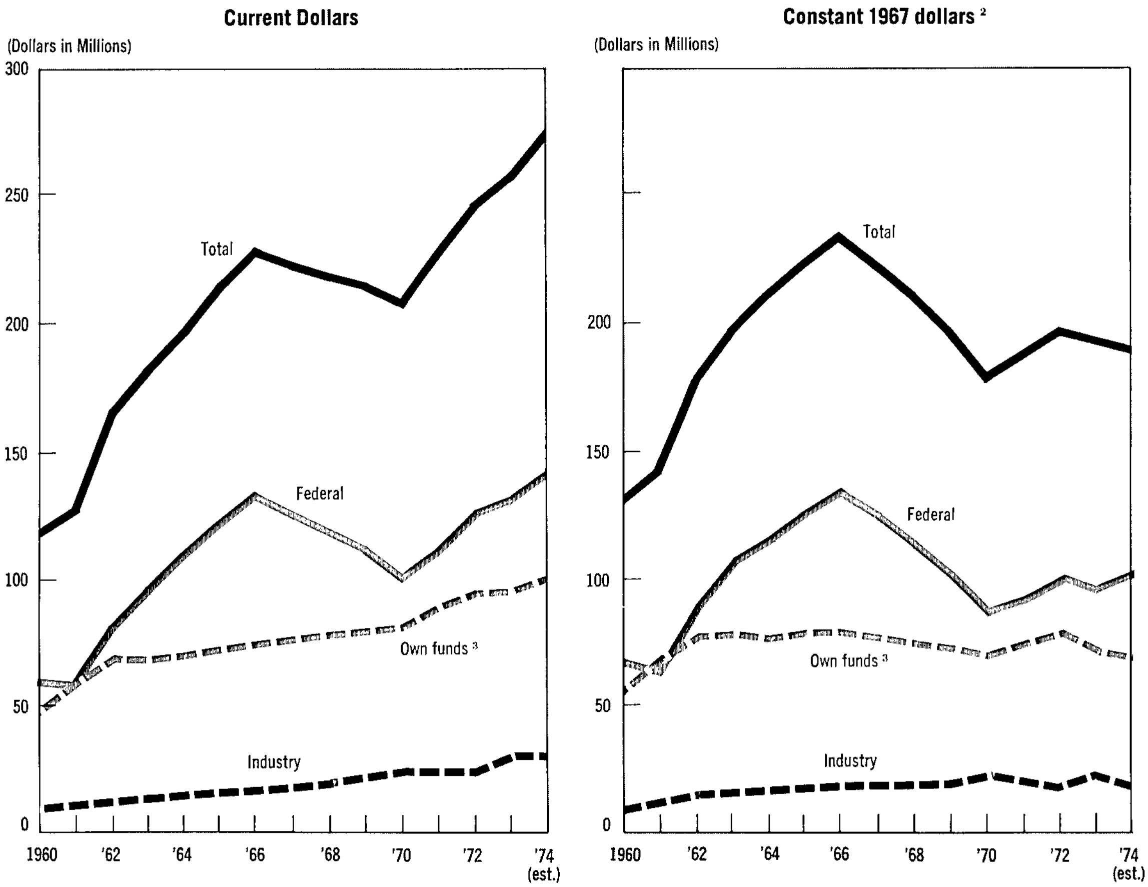
[1] GNP implicit price deflators used to convert current dollars to constant 1967 dollars.
SOURCE: National Science Foundation.

Research output by sectors. The research publications produced by each sector—university, government, industry, and other nonprofit organizations—are shown in figure 3-21 for five selected fields. (Data for each of the 13 fields are presented in Appendix table 3-21).

Universities were by far the largest producers of published research reports, followed by government, industry, and nonprofit organizations. The predominant role of academic institutions increased throughout the 1960-73 period covered by the study. By 1973, universities were responsible for an average of almost 75 percent of the publications in the 13 scientific fields, compared with some 60 percent of the total in 1960. The share of publications accounted for by the academic sector rose in all fields during the period, with the largest increases occurring in sociology, physics, chemistry, geology, and mathematics (including computer sciences).

Figure 3-19

Basic Research Expenditures in Nonprofit Institutions,[1] by Source, 1960-74



[1] Includes State-administered hospitals.
[2] GNP implicit price deflators used to convert current dollars to constant 1967 dollars.
[3] Includes State and local government funds.
SOURCE: National Science Foundation.

The Federal Government was the second largest producer of published research reports in 1973, with an average of 11 percent of the total reports from the 13 fields. The proportion of the total research publications produced by this sector declined, however, in all fields between 1960 and 1973, with the largest decreases occurring in oceanography, chemistry, and physics. In 1973, this sector accounted for a significant share of total research publications in the fields of astronomy (29 percent), oceanography (21 percent), geology (18 percent), and astronomy (16 percent).

Private industry's share of research publications in 1973 averaged 10 percent among all fields as a whole, with the largest fractions in the fields of engineering (44 percent), chemistry (18 percent), and physics (16 percent). The proportion of total publications for which this sector was responsible declined in all fields—other than the atmospheric sciences and oceanography—between 1960 and 1973. The largest declines were recorded in engineering, physics, and chemistry.

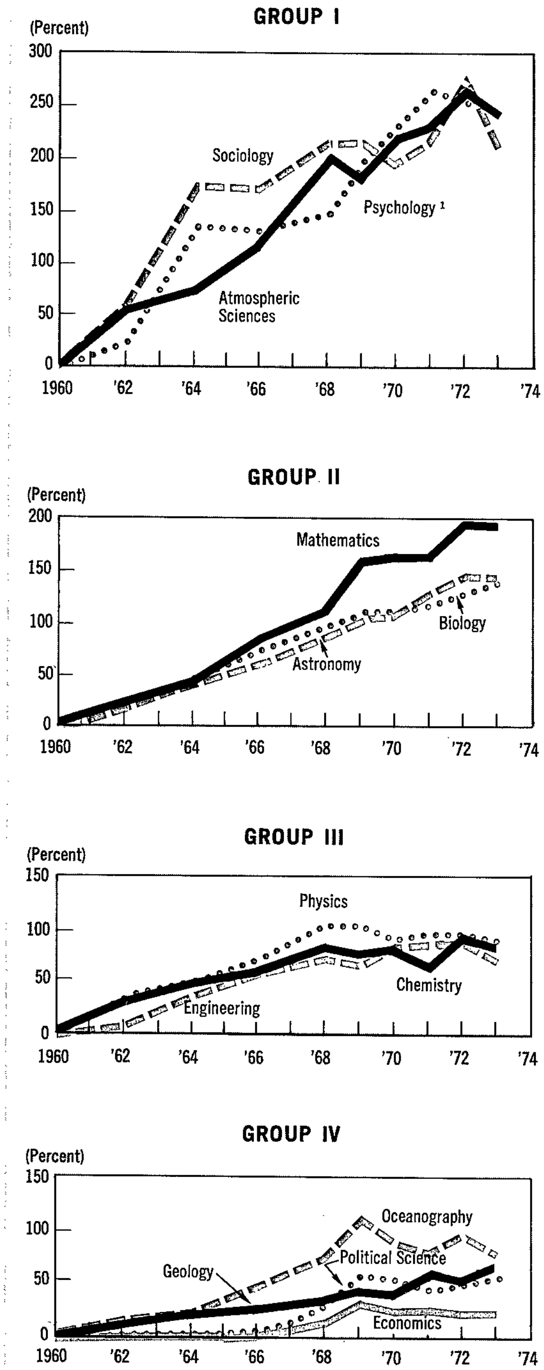
Nonprofit organizations produced the remaining 5 percent of total publications in 1973, down from some 10 percent in 1963.

It is clear from these indicators that academic institutions are predominant in the production

Figure 3-20

Relative Growth in Scientific Research Publications, by Selected Fields of Science, 1960-73

(Percent growth after 1960)



¹ Data not available for 1973.
SOURCE: National Federation of Abstracting and Indexing Services.

of research publications, and that their role *vis-a-vis* other sectors is increasing. The extent of their publication output appears high in relationship to the fraction of total financial resources for research which is expended by these institutions. (See figure 3-2 for the research expenditures by this and other sectors.)

Research publications and research expenditures. Publications in the five fields shown in figure 3-21 which were produced by universities were compared with the reported R&D expenditures for these fields. Expenditures in constant dollars were used for this purpose, with a "lag time" of two years between the expenditures and publications. (The limited available data on expenditures restricted the correlation to a short period of time, and did not permit exploration of alternate "lag times").

The results are presented in figure 3-22. A relatively close fit between lagged expenditures and publication output was found for the fields of biology, engineering, and mathematics. On the other hand, relatively large deviations between input and output were obtained in chemistry and physics, particularly in later years.

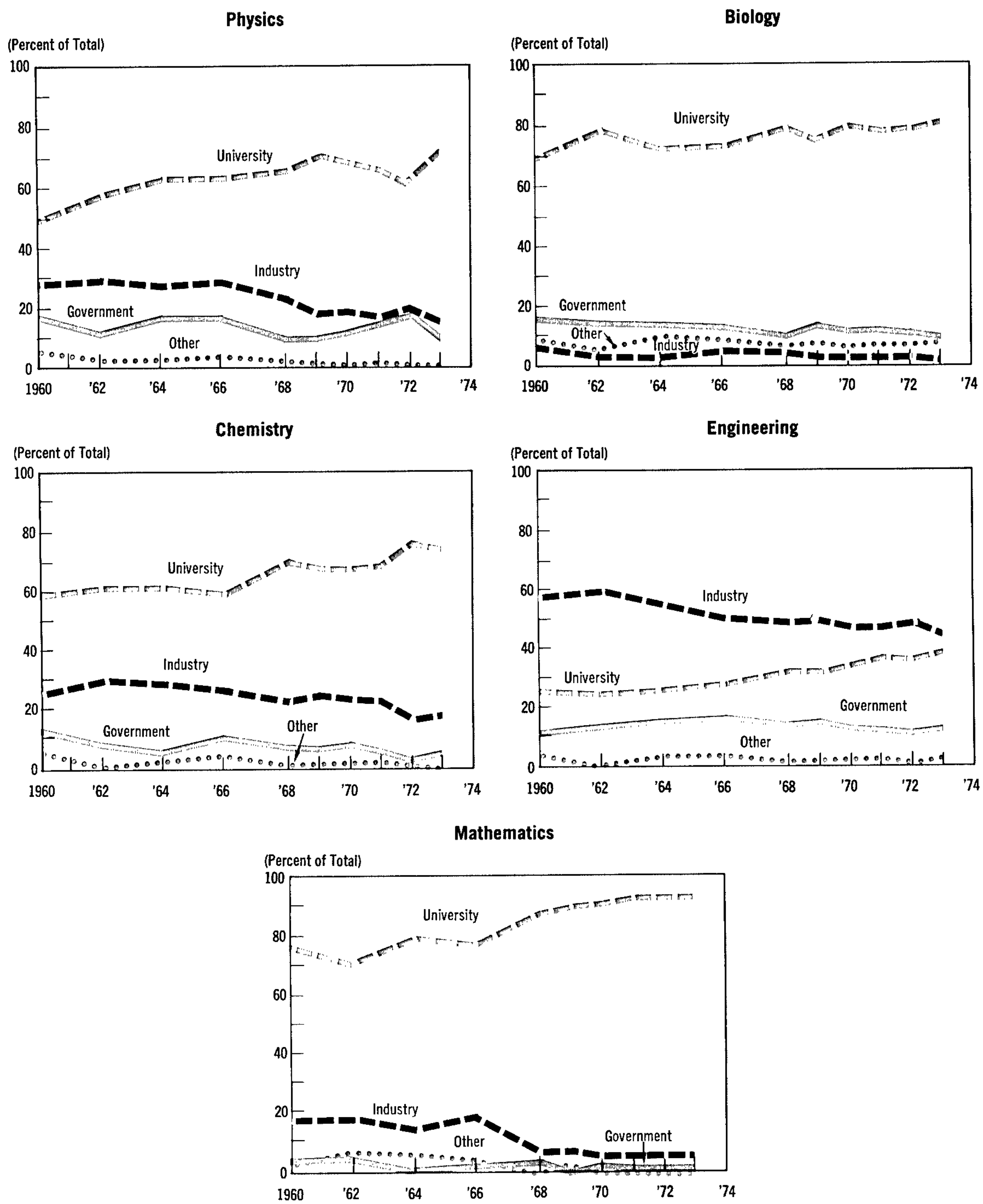
Basic research and technology

The relationships between basic research and eventual applications in modern technology are complex and difficult to trace. Certain aspects of these relationships were the subject of a special study upon which the data presented here are based. The study centered around 179 major advances in technology which occurred in the United States during the 1950-73 period. The patent documentation associated with each of the advances was examined to determine characteristics of the research which were cited as the origin of the invention.

The sample of 179 major advances covers ten broad areas of technology. These areas and examples of specific advances included in the study are shown below, on page 78

Figure 3-21

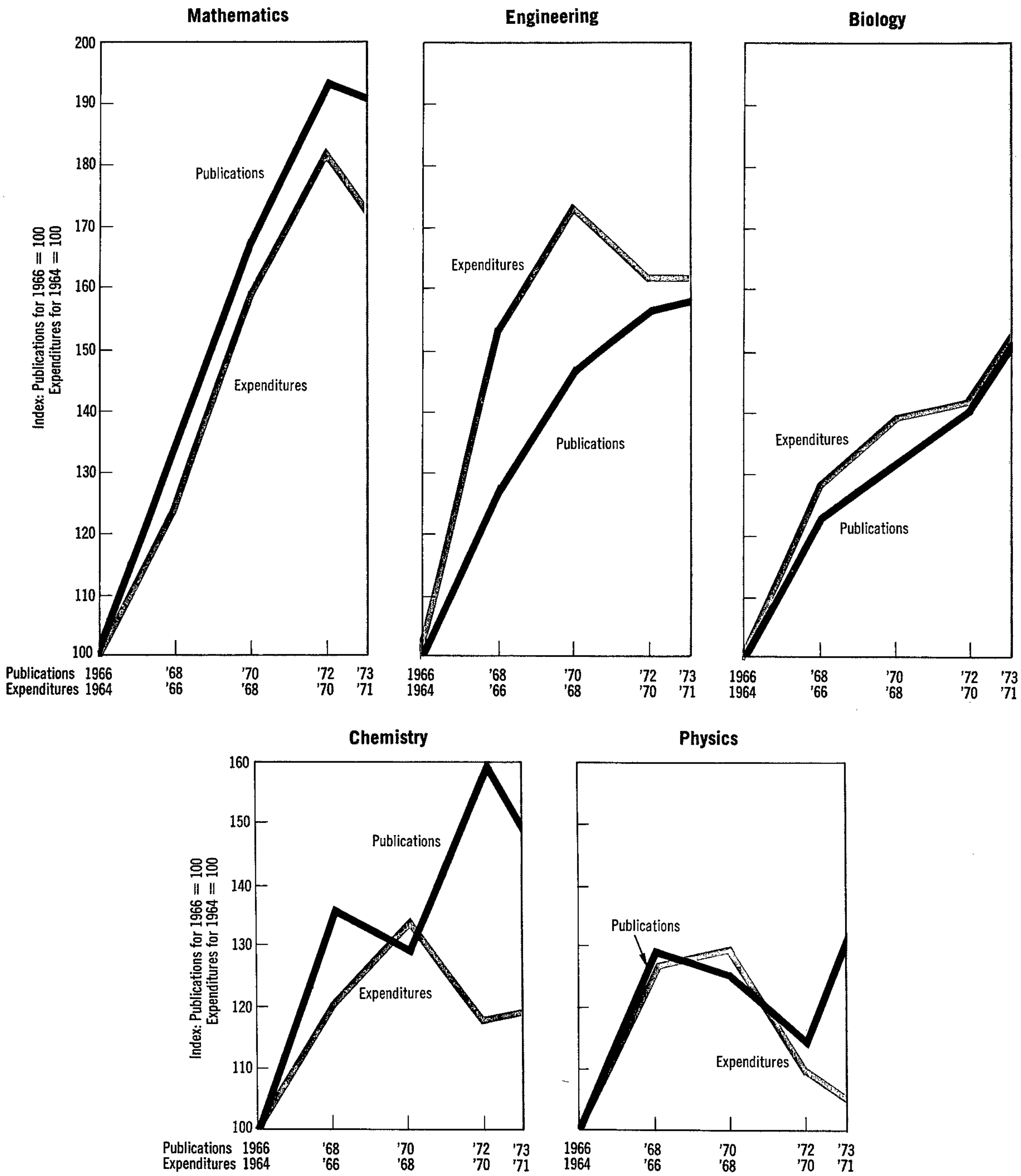
Publication Output for Selected Fields of Science, Percent of Yearly Totals by Sectors, 1960-73



SOURCE: National Federation of Abstracting and Indexing Services, 1974.

Figure 3-22

Research Publications and R&D Constant 1967 Dollar Expenditures[1] in Universities and Colleges, 1964-72



[1] GNP implicit price deflators used to convert current dollars to constant 1967 dollars.
SOURCE: National Science Foundation and National Federation of Abstracting and Indexing Servicese.

Technological areas	Number of advances
Chemicals	26
Electronic components	25
Nonelectrical machinery	22
Communication devices	20
Scientific, photographic & optical equipment	19
Computers & electronic data processors	17
Metals and alloys	16
Transportation systems & devices	16
Pharmaceuticals	12
Ceramics and other nonmetals	6
Total	179

Examples

Organo-phosphoric acids
Oral antidiabetic agent
Thermoelectric devices
Permutation decoder
Tunnel diode
Permanent magnetic materials
Wavefront reconstruction
Low energy electron sterilization
Processing of nuclear reactor fuel elements
Multiple speed transmission

Each technological advance is represented by a single "basic patent" in which the fundamental concept or idea embodied in the invention is presented for the first time in a patent application. The documentation provided with the application, as well as information added in the patent examination process, was reviewed in order to identify the research which was cited as the basis for the advance. Of the 179 examples, slightly more than 50 percent of the associated basic patents cited published research literature and/or other patents.[35] The data presented here are based on those patents in the sample which contained such citations.[36]

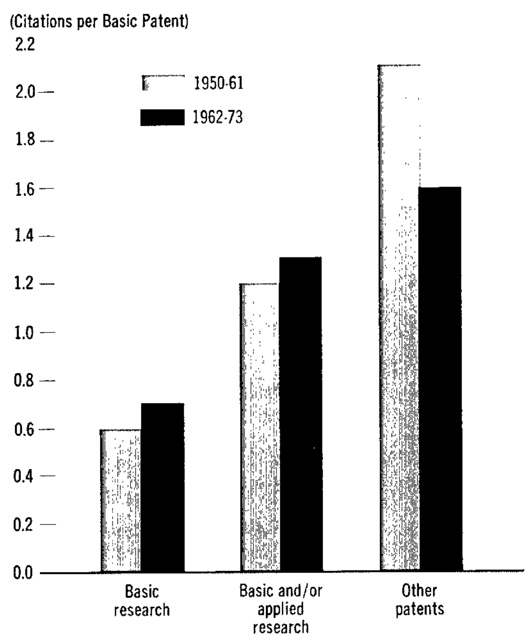
[35] The absence of citations in the remaining basic patents may have several causes, including the possible lack of candid disclosure by the patent applicant. Failure to make required disclosure has, in fact, resulted in a doubling of the number of patent invalidations over the past twnety years.

[36] For further information on the methodology of the study, see *Indicators of the Role of Science in Patented Technology*, Franklin Pierce College Law Center and the PTC Research Foundation, 1974 (A study commissioned specifically for this report).

Dependence on basic research. One important indicator of the relationship between basic research and technology is the extent to which new technologies or major advances in existing ones depend upon results from basic research. A measure of the incidence of such relationships is shown in figure 3-23. These findings show that other patents were cited more frequently than published research, but that differences between the two in citation frequency have narrowed considerably. The frequency of citation (number of citations per basic patent) increased by 17 percent for the basic and by 8 percent for the combined basic and applied research categories from the first to the second decade. On the other hand, the frequency of citation to other patents decreased almost 25 percent. These results suggest that more recent technological advances may depend increasingly on new scientific discoveries reported in the research literature.

Seven different fields of science and engineering were represented in citations to the research literature (figure 3-24). Almost an equal percentage of basic patents cited research in

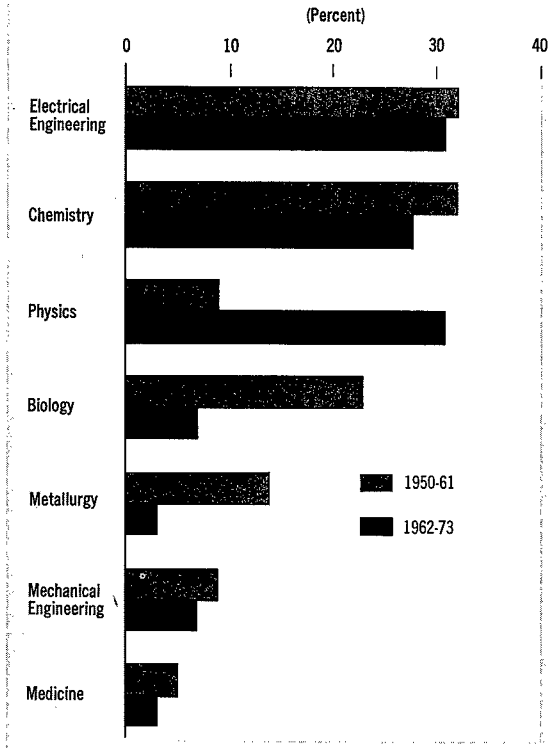
Figure 3-23
Citations per Basic Patent, by Type of Citation, 1950-61 and 1962-73



SOURCE: Franklin Pierce College Law Center and the PTC Research Foundation.

Figure 3-24

Percent of Basic Patents Citing Research Literature, by Field of Science and Engineering, 1950-61 and 1962-73



SOURCE: Franklin Pierce College Law Center and the PTC Research Foundation.

chemistry and electrical engineering (29 and 31 percent) over the 1950-73 period. Following these were physics (22 percent), biology (14 percent), metallurgy (8 percent), mechanical engineering (8 percent), and medicine (4 percent).

Sectors producing cited research. For each research citation, the institutional sector in which the cited research was performed was identified (figure 3-25). In the 1950-61 period, most of the research cited in the sample was performed in corporate laboratories (57 percent). In the 1962-73 period, however, corporate research was cited least frequently, accounting for only 15 percent of the research citations. Universities, on the other hand, rose from second place (28 percent) in 1950-61 to first place in 1962-73, with 54 percent of the cited research being performed in this sector. Research in academic institutions also accounted for most of the basic research citations in both periods, and applied research in the second period. These results should be considered, however, in respect to the total literature output of each of the four sectors. While most academic research is published without restraint, it is generally believed that research reports of corporate and government-affiliated scientists may be published less frequently because of their proprietary or national security character.

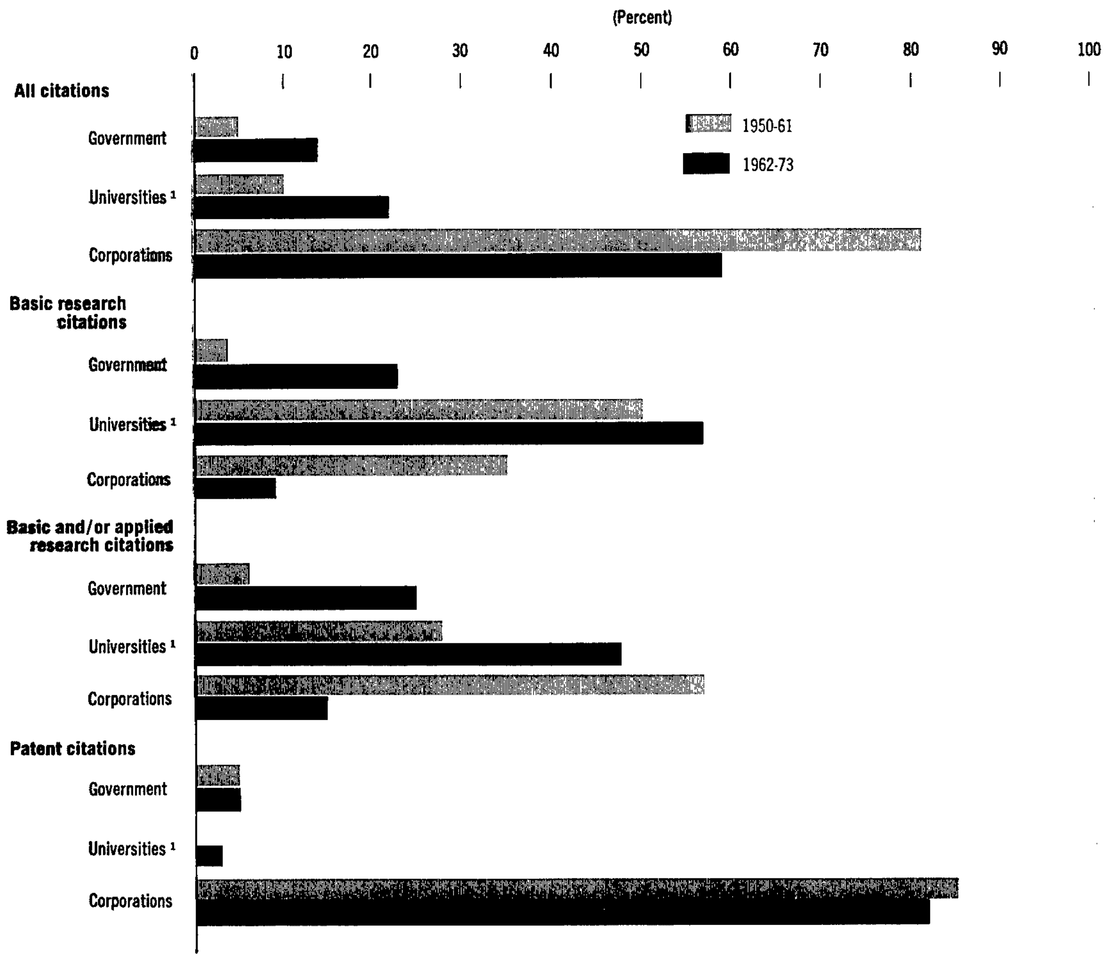
Time between research and application

Many of the results from basic research are not immediately incorporated into applied technologies. Often a long period of time is required to synthesize research results, or to await an economic or social need for a particular application in technology.

In the present study, the time between the research and its utilization in technology was defined as the interval between the publication date of the cited research and the date of patent application. The average time was found to decrease from seven to six years from the first to the second half of the 1950-73 period. The most recent period covered in the study (1970-73) has an average time interval of only three years, suggesting an increasingly rapid utilization of research results in modern technology.

Figure 3-25

Percent of Citations in Basic Patents, by Type of Citation and Source, 1950-61 and 1962-73



[1] Includes nonprofit institutions which account for less than 3 percent of all the citations.
SOURCE: Franklin Pierce College Law Center and the PTC Research Foundation.

Industrial R&D and Innovation

Industrial R&D and Innovation

INDICATOR HIGHLIGHTS

- Total expenditures for industrial R&D more than doubled between 1960-74, with one-third of the growth occurring after 1971; the large increases in recent years came almost entirely from industry's own funds, raising the total expenditures for industrial R&D to more than $22 billion in current dollars in 1974.
- Adjusted for inflation, total expenditures in 1967 constant dollars for industrial R&D were $15.2 billion in 1974, which was 11 percent lower than in 1968-69, the years of highest funding, and approximately equivalent to the funding level of 1965; in 1974, development activities accounted for 79 percent of total industrial R&D expenditures, compared with 18 percent for applied research and 3 percent for basic research.
- The total number of scientists and engineers engaged in industrial R&D increased in 1973 and 1974 to 360,600, following a decline from a peak employment level in 1969 of 387,000; such personnel supported by industry's own funds increased throughout the 1960-74 period, while the number supported by the Federal Government declined to pre-1960 levels.
- Expenditures for applied research and development in industry are focused on six product areas: communications equipment and electronic components, aircraft and parts, guided missiles and spacecraft, machinery, motor vehicles and other transportation equipment, and chemicals; these areas comprised nearly 70 percent of all such expenditures in 1973.
- Industrial R&D is concentrated in a few manufacturing industries and in a relatively small number of large companies within those industries; five industries accounted for some 80 percent of all industrial R&D expenditures in 1973 and a similar proportion of all R&D personnel, while the 100 companies with the largest R&D programs spent nearly 80 percent of all industrial R&D funds.
- Improvement of existing products was the reported goal of one-half of all industrial R&D in 1974, compared with approximately 35 percent for developing new products, and 15 percent for new processes.
- The R&D intensity[1] of manufacturing industries declined steadily after 1964 as a result of reduced Federal support for industrial R&D (primarily in the aircraft and missiles industry); in terms of industry support alone, however, the level of R&D intensiveness has changed little since the early 1960's.
- The most R&D-intensive industries were the largest producers of patented inventions, accounting for over 67 percent of all patents granted during the 1963-73 period; the majority of patents were for inventions in six major product fields: machinery, fabricated metals, electrical equipment, chemicals, professional and scientific instruments, and communications equipment.
- The most R&D-intensive industries produced the majority of a sample of major technological innovations during the 1953-73 period; these industries accounted for 66 percent of the innovations, followed by intermediate level industries with 24 percent, and the least R&D-intensive industries with 10 percent.
- Large companies (those with 10,000 or more employees) produced a greater number of the sample of innovations between 1953-73 than companies with less than 100 employees, but a smaller number than firms

[1] The proportion of net sales devoted to R&D and the number of R&D scientists and engineers relative to total company employment.

employing less than 1,000; small firms (those with less than 100 employees and those with 100-999 employees) produced more innovations per unit sales than larger firms throughout the period.

- The largest percentage of the sample of technological innovations produced during the 1953-73 period represented improvements in existing technology (41 percent), followed by those representing major technological advances (32 percent) and radical breakthroughs (27 percent); the fraction of radical innovations declined 50 percent between 1953-59 and 1967-73, while those rated as major technological advances increased proportionately.

- The most frequently cited sources of the underlying technology for the major innovations were research (applied and basic), followed by the transfer of technology from existing product lines of the innovating firm, licensing, and the purchase of technical "know-how" from other firms.

- Basic research was more often involved in product innovations characterized as radical breakthroughs (68 percent) than in those rated as major technological advances (48 percent) or improvements in existing technology (45 percent); applied research occurred with nearly equal frequency in all categories of the innovations studied.

Research and development is increasingly the basis and impetus for technological innovation in industry. The results of innovation are new and improved products, processes, and services. These are the elements of technological progress, through which many of the advances in the Nation's productivity, economic status (domestic and foreign), and standard of living take place.

While R&D is increasingly important in innovation, it is not sufficient by itself. Innovation is a complex process which occurs within a broad economic and social context, and which requires successful efforts in areas such as product design, engineering, manufacturing, and marketing. Although the innovation process is complex, expensive, and risky, the failure of a firm or an industry to be innovative may mean failure of the firm or industry itself, with consequent implications for the general economy.

As an activity, industrial R&D ranges from basic research, consisting of original investigations for the acquisition of scientific knowledge—to development, which attempts to translate acquired knowledge into new and improved products and processes. The character and extent of industrial R&D activity vary considerably, both in terms of the industry and size of the company involved. In general, R&D is viewed as an investment which competes for funds and other resources with alternative investments. For many firms, R&D is regarded as a necessary investment whose returns are believed to be competitive with those from other areas of potential resource allocation.

Indicators of the state of industrial R&D and innovation presented in this chapter consist of selected financial and human resources invested in R&D and measures of the outputs from such investment. The "input" indicators deal primarily with expenditures and scientific and engineering personnel involved in R&D, including trends in the R&D intensity of particular industries. "Output" indicators include measures of patents and technological innovations produced by R&D-performing industries, as well as factors which influence these activities. These measures, combined with R&D intensity and other characteristics, provide indicators of the relative inventiveness and innovativeness of different industries. The chapter concludes with a summary of the major findings from studies of the relationship of R&D and innovation to productivity and economic growth.

The present set of indicators provides a more comprehensive description of the state of industrial R&D than was provided by the first report in this series. The indicators, however, are still deficient in several respects, as discussed in later sections of this chapter.

RESOURCES FOR INDUSTRIAL R&D

Financial and human resources directed to industrial R&D represent principal "inputs" to R&D as well as approximate indicators of the

magnitude of the effort. Expenditures for R&D are presented initially for the total industrial R&D effort, followed by information on the source of funds and expenditures by specific industries. Trends in the number of scientists and engineers engaged in R&D are presented in terms of the Nation's overall effort in industrial R&D. These are followed by indicators of the division of R&D resources among the categories of basic research, applied research, and development, as well as the product fields on which the effort focuses. Data are presented also on certain institutional characteristics of industrial R&D—the distribution of R&D expenditures among companies of different size and among specific industries. The section concludes with trends in the R&D intensity of U.S. industries.

Financial and human resources for R&D represent only a small part of the total investment which industry makes for technological innovation, the principal aim of its R&D. Although little empirical data are available regarding total expenditures for innovation, estimates have been made of the typical distribution of costs among the several steps in the innovation process.[2] These estimates, which apply to successful innovations only, are shown in the table below.

Typical distribution of costs in successful product innovations

Activity	Percent
Research (advanced development-basic invention)	5-10
Engineering and designing the product	10-20
Tooling (manufacturing engineering)	40-60
Manufacturing start-up expenses	5-15
Marketing start-up expenses	10-25

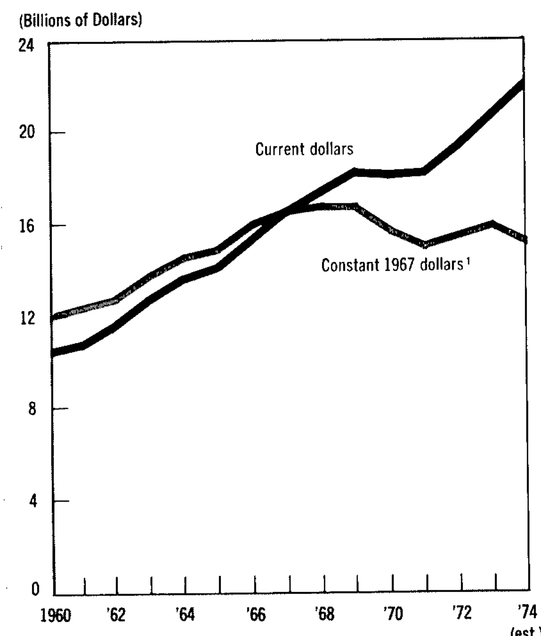
Although R&D (which encompasses all of the first step and most of the second) is estimated to account, on the average, for no more than 15-30 percent of the total costs of innovation, it is especially significant in that R&D often initiates and provides the basis for the subsequent steps in the innovation process.

Expenditures for industrial R&D

The total national expenditures for industrial R&D[3] are comprised of funds from both the Federal Government and private industry. The combined funding is shown in figure 4-1, in current and constant dollars. Total expenditures in current dollars more than doubled between 1960 and 1974, with one-third of the growth occurring after 1971. The average annual increase of just over $1.0 billion during that latter time was greater in absolute terms than in any other three-year interval between 1960 and 1974, and came almost entirely from an increase in funding by industry.

Total expenditures in current dollars for industrial R&D were over $22 billion in 1974. The growth in current dollar funding, however, was less than increases in inflation in recent

Figure 4-1
Industrial R&D expenditures, 1960-74



¹ GNP implicit price deflators used to convert current dollars to constant 1967 dollars.
SOURCE: National Science Foundation.

[2] *Technological Innovation: Its Environment and Management*, Department of Commerce, 1967. For a discussion of other estimates of the distribution of costs associated with innovation, see Edwin Mansfield, et. al., *Research and Innovation in the Modern Corporation*, (New York: W. W. Norton, 1971).

[3] Industrial R&D expenditures presented in this report include all costs incurred in support of R&D (i.e., salaries, laboratory equipment, overhead, etc.), but do not include associated capital expenditures. See *Research and Development in Industry, 1973*, National Science Foundation (NSF 75-315) p. 81, for further information on the scope of these costs.

years. As a result, total expenditures in constant dollars for industrial R&D were 11 percent lower in 1974 than in 1968-69, the years of highest funding, and approximately equivalent to the funding level of 1965.

Some perspective on the size of the investment in industrial R&D can be obtained by comparing it to other major investments by industry, such as those for new plant and equipment and for advertising. Such comparison is not intended to imply that identical factors determine levels of investment among the three areas. Indeed, the mix of investments in these areas varies from industry to industry.

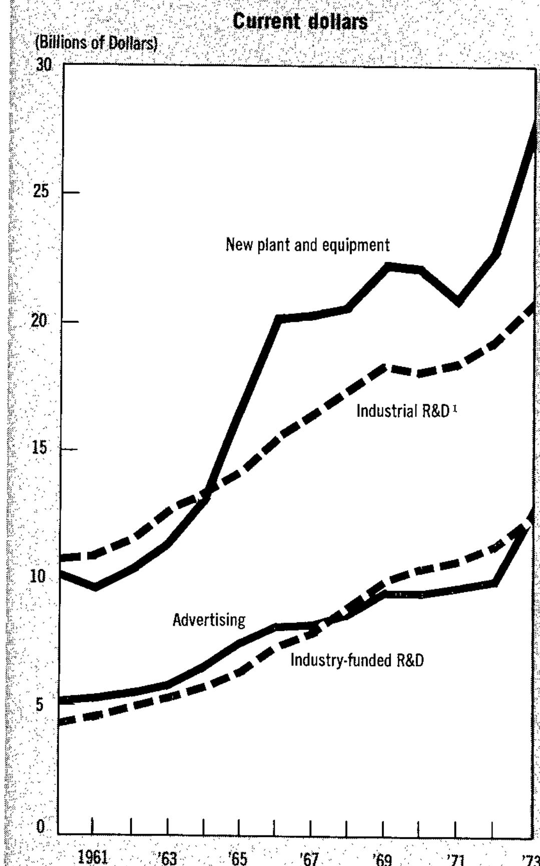
Trends in expenditures for the three purposes are shown in figure 4-2 for manufacturing industries which, as discussed later in this chapter, account for almost all industrial R&D expenditures. Total funds for industrial R&D were close in size to those for new plant and equipment during the early 1960's, but the latter grew more rapidly in subsequent years and by 1973 had exceeded total R&D expenditures in industry by approximately one-third. Expenditures for R&D from industry's own funds and for advertising[4] were closely comparable throughout the 1960-73 period.

Sources of funds for industrial R&D

As a consequence of increasing funds from industry and a leveling off of Government funds, industry replaced the Federal Government after 1967 as the major source of funds for industrial R&D (figure 4-3). By 1974, industry supplied 62 percent of all such funds, compared with only 42 percent in 1960. Federal funds for industrial R&D—principally from the Department of Defense (DOD) and the National Aeronautics and Space Administration (NASA)—reached a plateau in the late 1960's, dropped some 10 percent in the early 1970's as NASA and DOD support declined, and recovered in later years as DOD funding rose. These changes were reflected most prominently in the aircraft and missiles industry, and to a lesser extent in the electrical equipment and communication industry.

The extent of Federal support for industrial R&D differs substantially from one industry to

Figure 4-2
Expenditures for industrial R&D, advertising, and new plant and equipment by manufacturing industries, 1960-73

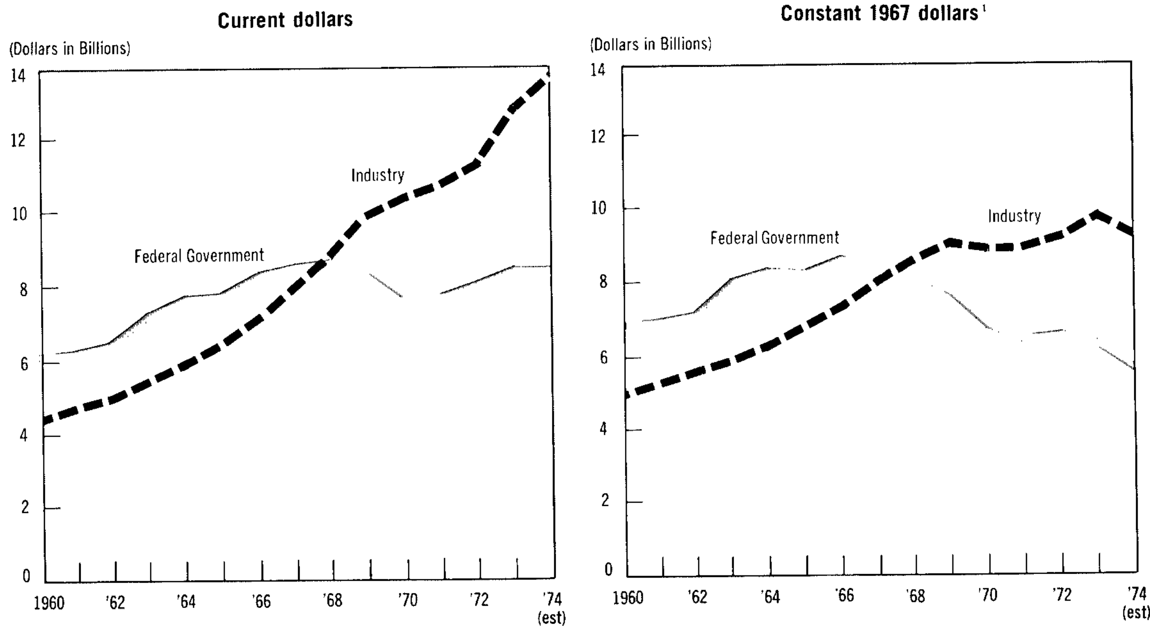


¹ Includes funds from all sources.
SOURCE: National Science Foundation and Department of Commerce.

[4] Includes expenditures by manufacturing corporations for newspaper, radio, television, magazine, and other miscellaneous local and national forms of advertising.

Figure 4-3

Expenditures for industrial R&D, by source of funds, 1960-74



[1] GNP implicit price deflators used to convert current dollars to constant 1967 dollars.
SOURCE: National Science Foundation.

another, as shown in the table below.[5]

Federal funds as a percentage of total industrial R&D expenditures, by industry, 1973

Industry	Percent
Aircraft and missiles	78
Electrical equipment & communication	50
Professional & scientific instruments	20
Motor vehicles and other transportation equipment	17
Machinery	16
Rubber products	12
Chemicals and allied products	10
Fabricated metal products	5
Primary metals	4
Petroleum refining and extraction	3
Stone, clay, and glass products	2
Textiles and apparel	2
Food and kindred products	1
Paper and allied products	1

[5] Federal support for nonmanufacturing industries amounted to 56 percent of their total R&D expenditures in 1973.

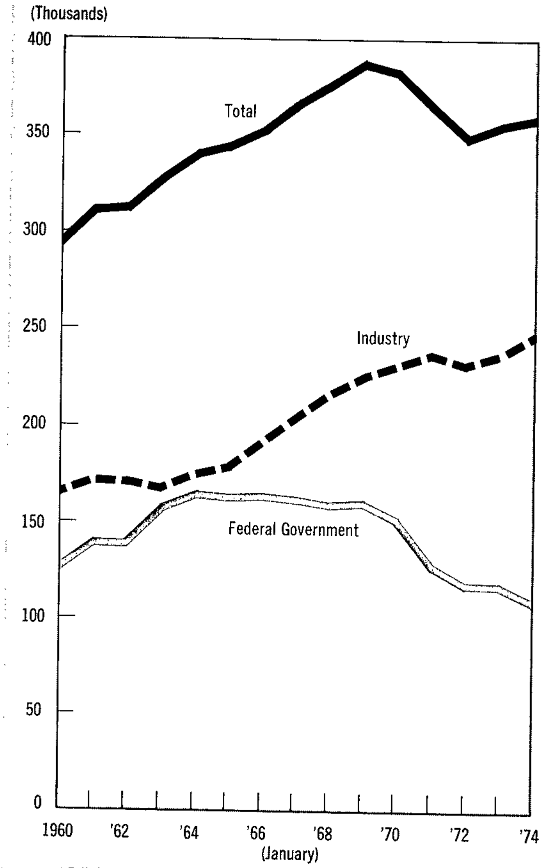
Industrial R&D personnel

Another indicator of the magnitude of industrial R&D is the number of scientists and engineers engaged in such activities. Trends in this measure are shown in figure 4-4, for the total of such personnel as well as for those who are supported by industry itself and those by R&D funds from the Federal Government. The total number of these personnel rose to a high of some 387,000 in 1969, declined 10 percent over the next three years, and rose slightly in both 1973 and 1974.

The decline in 1970-72 was concentrated among those scientists and engineers, principally the latter, supported by Federal R&D funds. The reductions, corresponding to the pattern of declines in Federal funding of industrial R&D described above, were primarily in the aircraft and missiles industry and secondarily in the electrical and communication, machinery, and chemicals industries. Some 70 percent of the reduction in numbers of federally supported R&D scientists and engineers was in these four industries.

Figure 4-4

Scientists and engineers[1] engaged in industrial R&D, by source of funds, 1960-74



[1] Full-time equivalent basis.
SOURCE: National Science Foundation.

Trends in the total number of R&D scientists and engineers in industry paralleled constant dollar expenditures for industrial R&D throughout most of the 1960-74 period (see figures 4-1 and 4-3). Such a correlation might be expected since the cost to industry for these personnel—a cost which represents a large fraction of the total cost of industrial R&D—has increased at approximately the same rate as inflation. Thus, the similarity of the two trends provides support for the use of the GNP implicit price deflator as a gross adjustment of current dollar expenditures to reflect more accurately the real level of financial input and the magnitude of effort.[6]

[6] A more complete discussion of the use of deflators for R&D expenditures appears in the chapter entitled "Resources for R&D" in this report.

R&D expenditures by specific industries

The extent to which a specific industry invests in R&D is dependent upon a diversity of factors, including competition within the industry and from other industries, government regulations requiring improved performance of products, the need of substitutes for and the conservation of natural resources, and the availability of funds and personnel for R&D. Nearly all manufacturing industries engage in some type of R&D activity. A few nonmanufacturing industries[7] also perform R&D, but their effort represents less than 5 percent of all industrial R&D spending.[8]

Expenditures for R&D in current dollars rose steadily in most industries from 1960 to 1973. In recent years, R&D spending has grown at a rate comparable to the early and mid-1960's, averaging over 7 percent per year between 1971 and 1973. The industries principally responsible for this growth are electrical equipment and communications, motor vehicles and other transportation equipment, machinery,[9] and chemicals and allied products. These four industries accounted for approximately 80 percent of the total increase in current dollar expenditures for R&D between 1971 and 1973.

Trends in expenditures for R&D in these and other major R&D-performing industries are shown in figure 4-5. In five of the seven specific industries, 1973 was the peak funding year for R&D in both current and constant dollars. The only major industry experiencing a large decline in R&D spending in either current or constant dollars during the 1960-73 period was aircraft and missiles, which dropped sharply after the late 1960's. Other industries, not shown in the figure, in which R&D expenditures in current and constant dollars were at their highest level in 1973 are: drugs and medicine, rubber products, fabricated metal products, communication equipment and electronic components, and optical, surgical and photographic instruments.

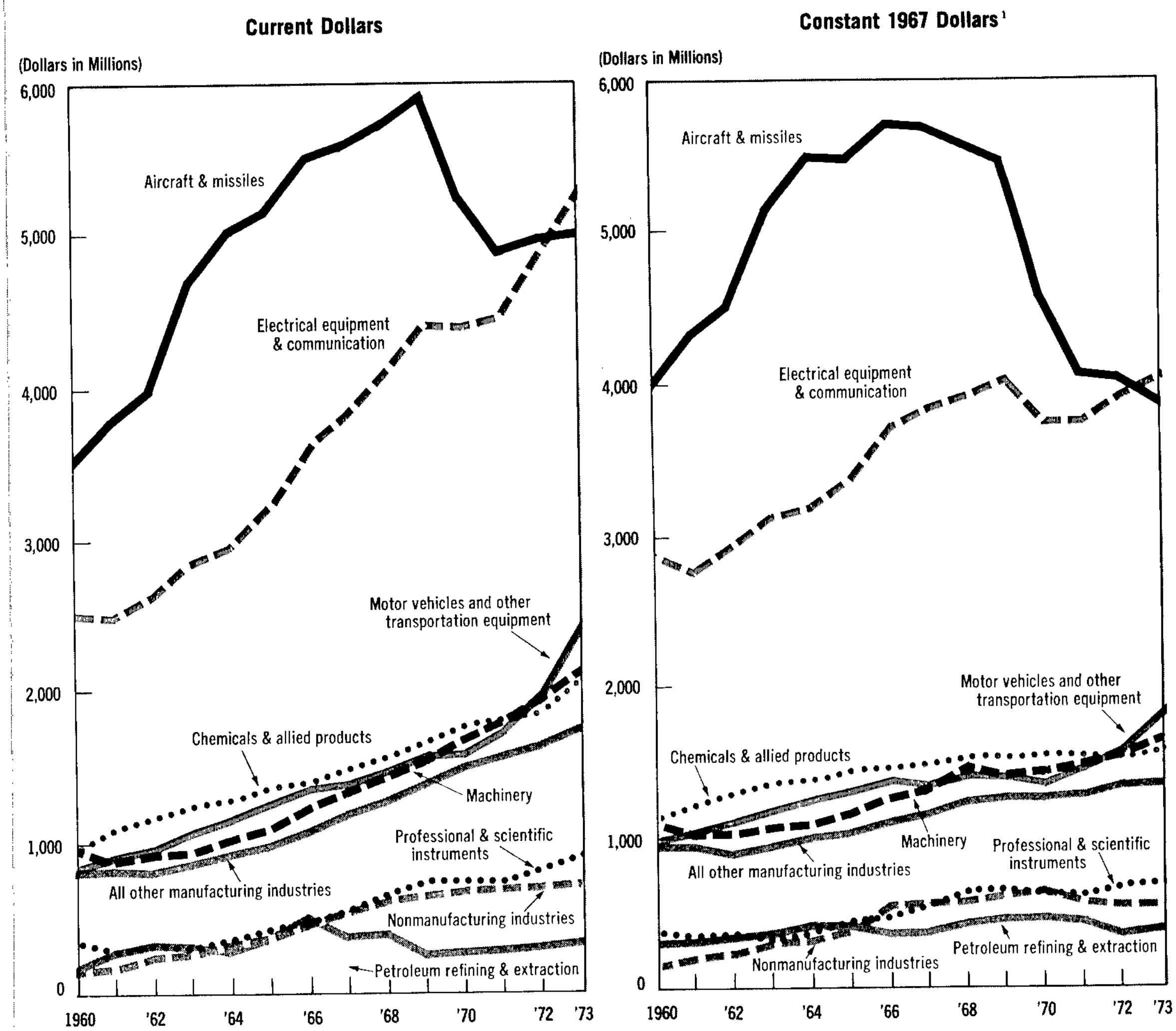
[7] These include, but are not limited to, agriculture, public utilities, finance, insurance, business services, medical and dental laboratories, and engineering and architectural services.

[8] *Research and Development in Industry, 1973*, National Science Foundation (NSF 75-315).

[9] Includes office, computing, and accounting machines; metal-working machinery; engines and turbines; farm machinery; construction, mining, and materials handling machinery.

Figure 4-5

R&D expenditures, by selected industries 1960-73



[1] GNP implicit price deflators used to convert current dollars to constant 1967 dollars.
SOURCE: National Science Foundation.

Expenditures for R&D in nonmanufacturing industries changed little after 1970.[10]

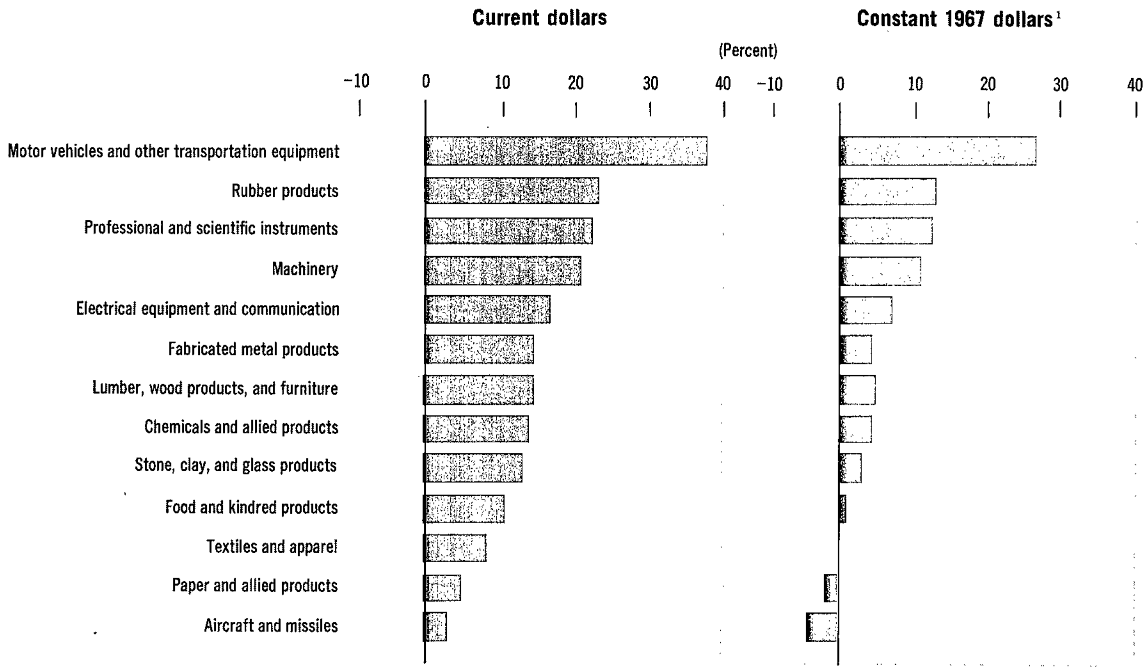
Industries differ substantially in the size of recent changes in their R&D expenditures. Industries with the largest relative growth in R&D spending between 1971 and 1973 are shown in figure 4-6.

[10] R&D expenditures for all industries are presented in Appendix table 4-5.

The overall pattern of R&D funding shown in figures 4-5 and 4-6 as well as elsewhere in this chapter, indicates a general shift in the Nation's industrial R&D effort. One aspect of the shift is that industry itself, rather than the Federal Government, has become the prime source of funds for industrial R&D. A second and related aspect is that the R&D is directed increasingly to "civilian" areas, i.e., to areas other than defense and space such as the development of new sources of energy, conservation of resources,

Figure 4-6

Industrial R&D expenditures, percent change, 1971-73



[1] GNP implicit price deflators used to convert current dollars to constant 1967 dollars.
SOURCE: National Science Foundation.

and improvement of the quality of the environment.[11] [12]

Energy is one of the civilian areas in which R&D expenditures have grown and are expected to increase still further in the years ahead. The exploration and development of new and alternative sources of energy for their own needs and the needs of the Nation as a whole have become important for many industries. As a result, expenditures by industry for energy-related R&D have risen almost 50 percent since 1972, reaching an estimated $1.1 billion in 1974.[13]

The petroleum industry is the leading performer of energy R&D, with expenditures of $325 million in 1973 and an estimated increase of 25 percent in 1974. The electrical equipment and communication industry is the second largest performer; these two industries combined accounted for over 65 percent of all energy-related R&D activities in industry in 1973. Advances in technology in the use of fossil fuels (particularly oil and coal) and nuclear energy are the principal objectives of the industrial R&D effort in this area.

[11] A similar shift of federally funded R&D toward civilian areas is discussed in more detail in "Resources for R&D" in this report.

[12] Historically, the Federal Government's role in industrial R&D dates from World War II, during which the principal emphasis was on defense-related R&D. Prior to that time, Federal support for industrial R&D was miniscule. (See Helen Wood, *Scientific Research and Development in American Industry*, Bureau of Labor Statistics, 1953; and Vannevar Bush, *Science—The Endless Frontier*, a report to the President, 1945.)

[13] "20-Percent Increase in Energy Activity Paces Industrial R&D Spending in 1973", *Science Resources Studies Highlights*, National Science Foundation (NSF 74-319), December 4, 1974.

R&D expenditures by character of work

Development activities receive by far the largest portion of total expenditures for industrial R&D, followed by applied and basic research. The proportion going for development efforts has ranged between 75 and 80 percent of total expenditures during the 1960-74 period, compared with nearly 20 percent for applied research and some 3 to 4 percent for basic research (figure 4-7).

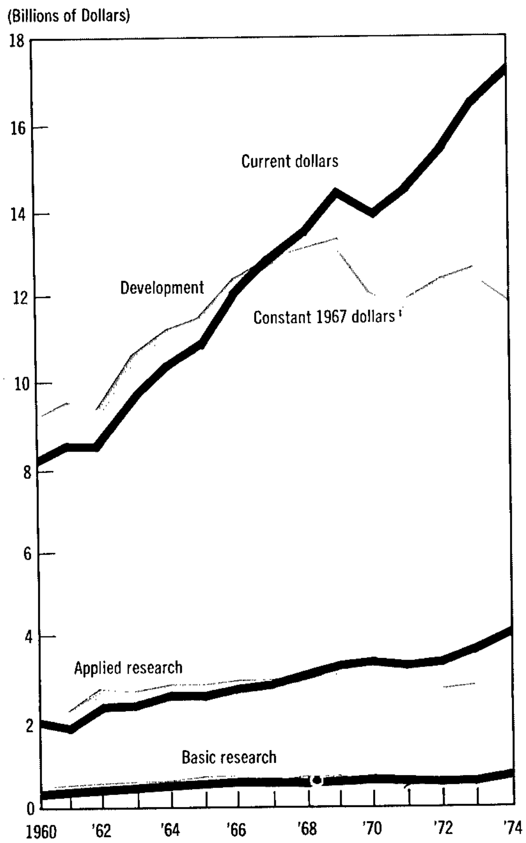
The emphasis on development efforts reflects the general nature of industrial R&D, which is usually focused on specific product lines and relatively short-range goals in terms of the time between R&D and expected returns from the investment. These tendencies are strengthened by the usually large proportion of total corporate R&D resources—funds and personnel—which are controlled by divisional managers of firms whose major focus is often on existing product lines and processes.

Expenditures in current dollars for applied research and development generally increased each year between 1960 and 1974, whereas funding of basic research has remained at a relatively fixed level of some $600 million since 1965. Constant dollar expenditures, on the other hand, declined after 1969 for development efforts, due primarily to reductions in Federal funds, whereas those for applied research have changed little since 1964. Funding of basic research in constant dollars has fallen since the mid-1960's, reaching a level in 1974 which is approximately equal to that of 1961.

The distribution of funds among these categories of R&D differs according to the sources of funds, with industry providing most of the funds for basic and applied research and a lesser, but still the largest, share of development funds. In 1974, for example, industry funded 78 percent of its own basic research and 75 percent of its applied research, compared to 59 percent of its development.[14]

Figure 4-7

Industrial R&D expenditures for basic research, applied research, and development, 1960-74



¹ GNP implicit price deflators used to convert current dollars to constant 1967 dollars.
SOURCE: National Science Foundation.

Applied R&D in product fields

Over the last two decades there has been a rapid expansion and diversification of firms into new product lines, markets, and technical fields. Thus, R&D data reported by a firm may include expenditures in several product fields, in addition to the single, major field which determines the broad industrial category to which the firm is assigned. Therefore, R&D expenditures in terms of product areas, rather than industries, are more indicative of the actual composition and focus of the national effort in industrial R&D.

Expenditures for applied research and development[15] are concentrated in 6 of the 15 broad product fields used for classification purposes.[16] These 6 fields, and the percentage of

[14] *National Patterns of R&D Resources, 1953-75*, National Science Foundation (NSF 75-307).

[15] Expenditures for basic research are excluded since such research, by definition, is not directed toward specific products.

[16] See Appendix table 4-12 for a listing of these product fields.

the total applied R&D expenditures each received in 1973, are shown in the table below.[17]

Distribution of applied R&D expenditures, by selected product field, 1973

Product field	Percent
Communication equipment and electronic components	17
Aircraft and parts	12
Guided missiles and spacecraft	12
Machinery	11
Motor vehicles and other transportation equipment	10
Chemicals[18]	7

Substantial changes in applied R&D expenditures have occurred in more specific product fields in recent years. Fields with an overall increase or decrease in constant dollar expenditures of 10 percent or more during the 1971-73 period are cited below.

Concentration of industrial R&D

The U.S. industrial R&D effort is concentrated within relatively few industries, and within a small number of large companies within these industries. Throughout the 1960's and early 1970's, over 80 percent of all industrial R&D expenditures and over 77 percent of industrial scientific personnel engaged in R&D were concentrated in only five industries—aircraft and missiles, electrical equipment and communications, chemicals and allied products, machinery, and motor vehicles and other transportation equipment (figure 4-8). The largest change over the period occurred in the aircraft and missiles industry, where R&D expenditures declined significantly in relative terms after the mid-1960's.

Similar trends are evident in the concentration of R&D scientists and engineers in these same five industries. The aircraft and missiles industry is seen to account for a declining proportion of the total industrial R&D personnel resources beginning in 1963. This industry, however, in combination with the electrical equipment and communications industry employed over 46 percent of all scientists and engineers engaged in industrial R&D in 1973 (figure 4-9).

To a significant degree, the concentration of industrial R&D in a few industries reflects the influence of Federal R&D contract work, primarily in the defense and space areas. In 1973, for example, almost 92 percent of all federally funded R&D in industry went to these five industries. Federal funds to these industries ranged from about 10 percent of the total R&D expenditures in the chemicals and allied products industry, to some 50 percent in electrical equipment and communications, and to over 80 percent in the aircraft and missiles industry. Together, Federal funding for R&D in these five industries represented over 35 percent of the total expenditures for industrial R&D in 1973.

A similar pattern is observed in regard to the concentration of scientific personnel. The five industries cited above employed 90 percent of all

Percent change in constant dollar applied R&D expenditures, by product field, 1971-73

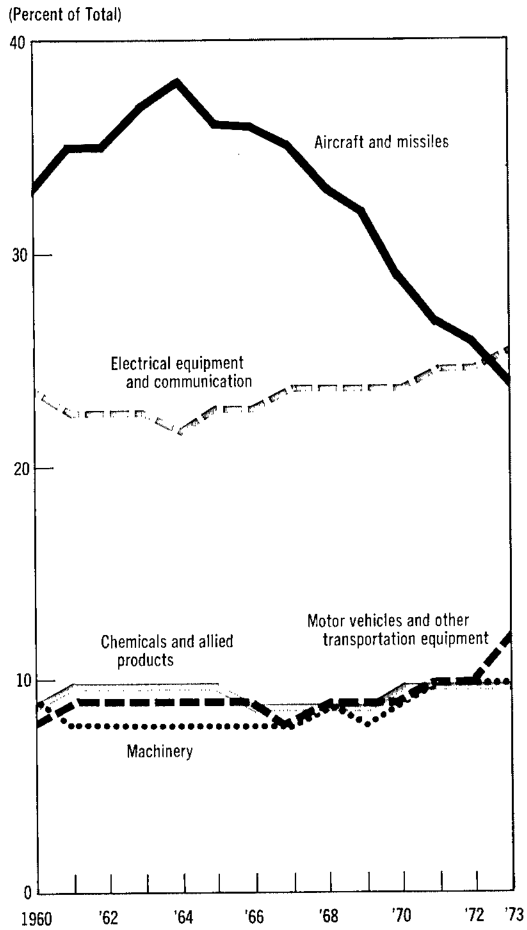
Increases of more than 25 percent		Increases of 10-25 percent		Decreases of 10 percent or more	
Ferrous metals & products	87	Electrical industrial apparatus	24	Guided missiles	-20
Transportation equipment, except motor vehicles	59	Farm machinery & equipment	19	Metalworking machinery and equipment	-20
Textile mill products	36	Office, computing, and accounting machines	19	Nonferrous metals & products	-19
Motor vehicles & equipment	35	Ordnance, except guided missiles	11	Agricultural chemicals	-19
Professional & scientific instruments	32	Stone, clay, & glass products	10	Plastics materials & synthetic resins	-10
Engines & turbines	30	Communication equipment & electronic components	10		
Rubber & plastics products	26				

[17] For additional data on these and other product fields, see *Research and Development in Industry, 1973*, National Science Foundation (NSF 75-315).

[18] Except drugs and medicine.

Figure 4-8

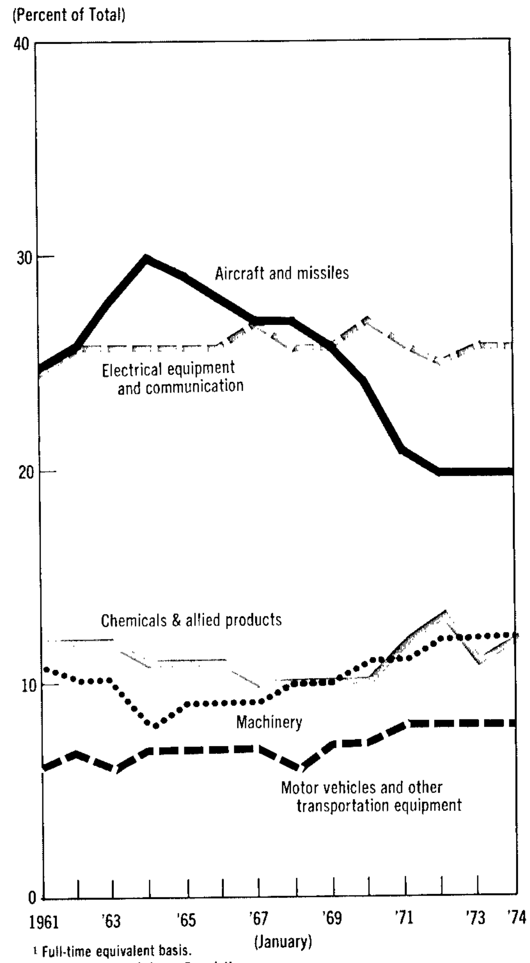
Distribution of industrial R&D expenditures among selected industries, 1960-73



SOURCE: National Science Foundation.

Figure 4-9

Distribution of scientists and engineers[1] engaged in industrial R&D among selected industries, 1961-74



[1] Full-time equivalent basis.
SOURCE: National Science Foundation.

federally supported R&D scientists and engineers in industry as of January, 1974, representing almost 30 percent of all R&D scientists and engineers employed by industry.

Most of the R&D activity in industry is further concentrated within a small number of large companies.[19] Of a total of over 11,000 R&D-performing companies in 1973, the 300 companies with over 10,000 employees accounted for more than 80 percent of all industrial R&D expenditures. Thirty-one of these companies reported R&D programs costing more than $100 million, for a total of almost $12 billion, or more than 60 percent of all R&D expenditures by industry. Thus, even small percentage changes in the level of R&D activity in a few large companies can have a substantial effect on the overall U.S. industrial R&D effort.

When viewed against the totality of companies which comprise industry, or even the manufac-

[19] The words "company" and "firm" are used interchangeably in this report, even though they may have slightly different meanings in other contexts. Each term denotes a business organization consisting of one or more establishments under common ownership or control.

turing sector alone, the number of individual companies with a formal R&D program is comparatively small. For example, in 1967 (the latest year for which Census data on the total number of manufacturing companies is available) only 11,200 companies, or less than 5 percent of all manufacturing companies, reported having any R&D program. Furthermore, the proportion of companies conducting R&D differed substantially by company-size groups. In 1967, only 4 percent of all manufacturing companies with under 1,000 employees conducted any R&D, while 55 percent of companies employing between 1,000 and 5,000 persons, and 88 percent of companies with 5,000 or more employees reported such efforts.

Among the performers of R&D is a subset of the small company group which consists of "high technology" firms whose main objective is the performance of R&D and the development of new products. These new research-based enterprises represent only a small percentage of the total industrial R&D effort, but they have often evolved into large firms that dominate market segments and, in some cases, entire industries. These science-based firms are predominantly located in industries such as electronics, communications, computers, aircraft, and nuclear and medical instruments.[20]

R&D intensity

The proportion of an industry's human and financial resources which are utilized for R&D may be regarded as a measure of the "R&D intensity" of that industry. The indices used frequently for quantifying the level of R&D intensity are (1) total and company funds expended for R&D as a percentage of net sales and (2) the number of R&D scientists and engineers per 1,000 employees. Based on these indices, each of the 15 largest R&D-performing industries in the manufacturing sector was

Measures of R&D intensity, by industry, 1961-72

Industry	Mean over the 1961-72 period		
	R&D scientists & engineers per 1,000 employees	Total funds for R&D as a percent of net sales[21]	Company funds for R&D as a percent of net sales[21]
Group I			
Chemicals & allied products	37.8	4.0	3.5
Machinery	25.9	3.9	3.1
Electrical equipment & communications	47.2	8.5	3.6
Aircraft & missiles	88.6	20.9	3.5
Professional & scientific instruments	33.9	5.9	4.1
Mean for group I	47.1	8.2	3.5
Group II			
Petroleum refining & extraction	15.8	0.9	0.9
Rubber products	17.8	2.0	1.7
Stone, clay & glass products	10.7	1.6	1.5
Fabricated metal products	12.8	1.3	1.2
Motor vehicles & other transportation equipment	19.4	3.3	2.5
Mean for group II	16.4	1.9	1.6
Group III			
Food & kindred products	7.2	0.4	0.4
Textiles & apparel	3.1	0.5	0.5
Lumber, wood products & furniture	4.7	0.5	0.4
Paper & allied products	8.5	0.9	0.8
Primary metals	5.6	0.8	0.8
Mean for group III	6.0	0.6	0.6

[20] For further information on R&D in small companies, see Thomas Hogan and John Chirichiello, "The Role of Research and Development in Small Firms", in *The Vital Majority: Small Business in the American Economy*, Small Business Administration, 1974.

[21] Total net sales by Group I industries over the entire 1961-72 period were only 25 percent larger than sales by industries in Group II and approximately 50 percent larger than those of Group III industries.

placed into one of three groups according to its relative level of R&D intensity over the 1961-72 period. These groups, each consisting of five industries, are shown in the table below along with their R&D intensity indices, with Group I industries being the most R&D-intensive and Group III the least.

As the table shows, the level of R&D intensiveness among industries within each group is within a relatively close range regardless of the specific index chosen. Furthermore, the R&D intensity of each group is separated from the next by approximately a factor of three.

The R&D intensity of manufacturing industries overall has declined steadily since 1964. As shown in figure 4-10, the declines occurred almost exclusively in the most R&D-intensive industries (Group I), and were caused primarily by reductions in the level of Federal support for industrial R&D after the mid-1960's. Aside from the changes produced by declining Federal support, the R&D intensity of each group of industries has changed little since 1961.

The assignment into three major groups of industries exhibiting approximately the same level of R&D activity provides a convenient and direct method for relating R&D to the outputs and returns from such effort, as shown in the next section of this chapter.

OUTPUTS FROM R&D AND INNOVATION

Earlier sections of this chapter dealt largely with the resources employed in industrial R&D and structural aspects of the system. This section attempts to provide indicators of some of the outputs and returns from R&D—aspects which are considerably more difficult to measure than inputs.

The principal indicators in this section deal with trends in technological invention and innovation. Measures of invention are in terms of patents and include indicators of the areas and magnitude of inventive output, sources of invention, product areas involved, and relationships with R&D intensity. Indicators of innovation are based upon new industrial products embodying major advances in technology and include characteristics of innovating organizations, innovativeness of different industries, relationship to investment in R&D, time between invention and innovation, and the role of research.

The measures of output presented here represent only a step toward the array of indicators needed for the industrial sector. Present measures are small in number, broad in scope, and restricted generally to relatively direct outcomes of R&D. Lacking are indicators such as reduced costs, gains in an industry's productivity or increases in sales which result from R&D. The measures, in addition, do not encompass the qualitative improvements in industrial products and processes which often constitute the major form of return from R&D investment.

The present indicators, furthermore, do not specify the separate and distinct contribution of R&D to invention and innovation. As noted earlier, invention and innovation result from a complex of interacting factors—economic, social, and technical. Analytical efforts to date have not been successful in determining the precise contribution of the individual factors, including that of R&D. Thus, indicators presented here should be regarded as approximate measures of the relationship between this factor and invention or innovation.

The impact of technological innovation on productivity and economic growth is, in turn, understood only in general terms. Present knowledge of the causal connection between innovation and economic returns is not sufficient for developing quantitative indicators of the relationship. In lieu of such indicators, the major conclusions derived from studies in this area are summarized.

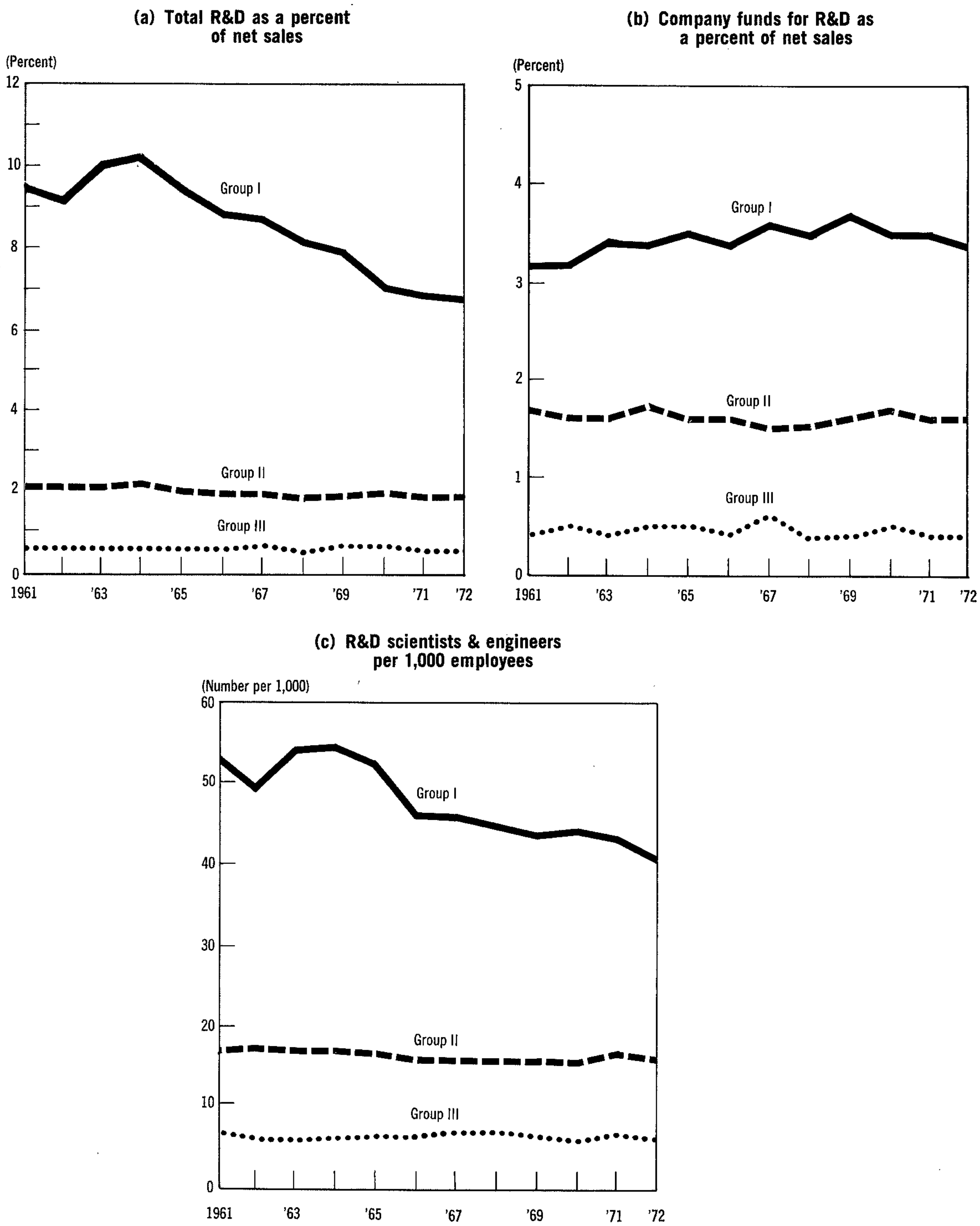
Finally, the indicators in this chapter do not include measures of the negative impacts and side-effects of technological innovation. These costs may be extensive in human and social terms, ranging from the loss of jobs to the pollution of our environment. The determination of these costs and their assessment relative to benefits, is necessary for the wise management of innovation. Valid indicators of these costs, however, are exceedingly difficult to develop; it is for this reason, rather than a lack of recognition of their need, that such indicators are not provided in this report.

Objectives of industrial R&D

In general, industry views R&D as a means to remain competitive and profitable. Most industrial R&D is an attempt to focus science and technology on improving existing products and

Figure 4-10

R&D intensity of U.S. manufacturing industries, 1961-72



SOURCE: National Science Foundation.

processes and on developing new ones. Some R&D in the form of basic research is performed to gain new insights into areas of company interest, and the results from these efforts may be incorporated eventually into new or improved products. In this way, R&D assists companies to maintain existing markets or to expand into new ones, to reduce production costs, and to increase profits.

The importance of improving and developing new products and processes, and the associated levels of R&D, vary among industries. In addition, the emphasis placed on new developments versus improvements differs—over time and among individual companies and industries. Some indication of the relative emphasis of the R&D programs of manufacturing industries during 1974 is indicated below.[22]

Objectives of industrial R&D programs, 1974

Objective	Percent of R&D expenditures
Improving existing products	50
Developing new products	36
Developing new processes	14

As shown in the table, one-half of the R&D expenditures are aimed at improving existing products. Only three industries—electrical equipment and communication, professional and scientific instruments, and food and kindred products—reported new product development as the principal objective of their R&D programs. Petroleum refining and extraction and the nonferrous metals industries were the only two in which new process developments received the largest share of R&D funds. All other manufacturing industries in 1974 emphasized the improvement of existing products in their R&D programs. Product improvements were also the predominant type of innovations found in a sample of major innovations reported later in this chapter under "Technological innovation."

Some industries depend upon R&D more than others. This dependency might be expected to be greatest among those industries relying most heavily on sales from new products, rather than on the improvement of existing ones. Although data are lacking on actual sales from new products, information is available on the sales expected from such products. These estimates, expressed as a percentage of total expected sales, are summarized in the table below.[23] As indicated, the most R&D-intensive industries have expected a higher proportion of their sales to be in new products than the two groups of less R&D-intensive industries.

Expected sales from new products[24] as a percent of future sales

R&D intensity	Mean percent		
	1969-70	1971-72	1973-74
Group I	27	26	24
Group II	15	15	20
Group III	11	15	11

The three industries reporting the highest proportion of R&D expenditures for new product development (electrical equipment and communications, machinery, and professional and scientific instruments) are among the five industries expecting the largest proportion of sales from new products during the 1969-74 period.

The expected level of new product sales appears to have declined slightly for Group I industries overall, and increased for Group II industries since 1969-70. This decline in Group I industries may result from a longer term shift away from the development of new products toward innovations representing improvements in existing technologies. (See the later section in this chapter entitled "Radicalness of the innovations.")

Patented inventions

Patented inventions are one of the more direct outputs of industrial R&D. They often represent actual or potential advances in technology, and thus indicate, to some extent, the level, direc-

[22] *Business' Plans for R&D Expenditures, 1975-78*, McGraw-Hill Publications Co., May, 1975. (Strictly comparable data are not available for earlier years.)

[23] The data presented in the table are based on an analysis, commissioned especially for this report, of information from *Business' Plans for R&D Expenditures*, McGraw-Hill Publications Co., Economics Department, annual surveys, 1966-74.

[24] "New products" were defined as those expected to be introduced into the market within three years following the time of the survey. What constitutes a "new product" and the extent to which it differs from previously existing products may vary among industries and/or companies.

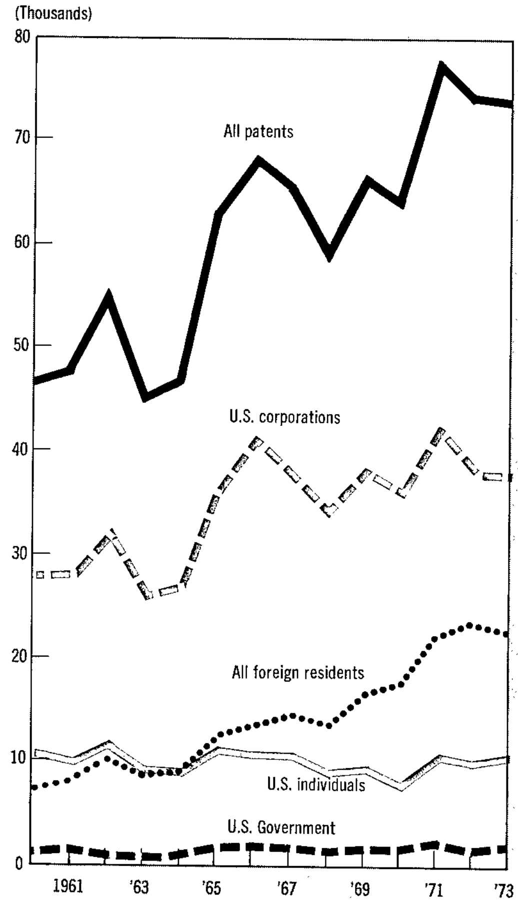
tion, and success of inventive and innovative activity of a technological nature.[25] In some cases, the number of patents may understate the actual level of invention. For various reasons, an invention may never be patented; as for example, when the protection afforded by a patent is less important than the rapid introduction of a new product into the marketplace or where the expected protection does not offset the hazard of disclosure. Patent output may, on the other hand, overstate the level of invention to some extent. This situation may arise, for example, when numerous defensive patents are obtained around basic inventions. Finally, of course, patents vary greatly in their economic and technological significance. Many patented inventions become embodied in new and improved products, processes, and services—only some of which eventually lead to substantial economic returns.

The majority of patented inventions now come from R&D programs in large industrial laboratories. Many of the others, including some of the more significant ones, come from "independent" inventors.[26] As indicated in the "Basic Research" chapter of this report, major patented inventions from all sources appear to be based increasingly upon R&D.

The number of U.S. patents granted increased between 1960 and 1973, though fluctuating from year to year[27] (figure 4-11). Two principal sources of patents were responsible for the overall increase—U.S. corporations and residents of foreign countries. The patent output of U.S. individuals and the Federal Government remained at relatively low and constant levels during the period. The number of U.S. patents granted to residents of foreign countries showed the greatest overall gain, with the largest increases occurring after 1968. In

Figure 4-11

U.S. patents granted for inventions, 1960-73



SOURCE: U.S. Patent Office.

1973, foreign residents were granted over 30 percent of all U.S. patents, as compared with 16 percent in 1960. (The significance of foreign patent activity in the U.S. is discussed in the chapter entitled "International Indicators of Science and Technology" in this report).

The patent output of U.S. industry (i.e., patents assigned to U.S. corporations) accounted for the largest proportion of total patents granted throughout the 1960-73 period.[28] The

[25] A major study on this topic was published in 1966 by Jacob Schmookler, *Invention and Economic Growth* (Cambridge: Harvard University Press). A recent reappraisal of this work by Nathan Rosenberg is presented in "Science, Invention and Economic Growth", *Economic Journal*, Vol. 84 (March 1974), pp 90-108.

[26] For more detailed information on this topic, see David Hamberg, "Invention in the Industrial Research Laboratory", *Journal of Political Economy*, Vol. 71 (April 1963). See also, "Concentration, Invention, and Innovation", U.S. Senate Antitrust Subcommittee, 89th Congress, Part III; and *Technological Innovation: Its Environment and Management*, Department of Commerce, 1967.

[27] The year to year fluctuations are associated primarily with the processing and examination of patent applications by the U.S. Patent Office, rather than variations in the number of patent applications *per se*.

[28] A recent report, *A Review of Patent Ownership*, Office of Technology Assessment and Forecast, U.S. Patent Office, January 1975, identified specific companies involved in active technological areas.

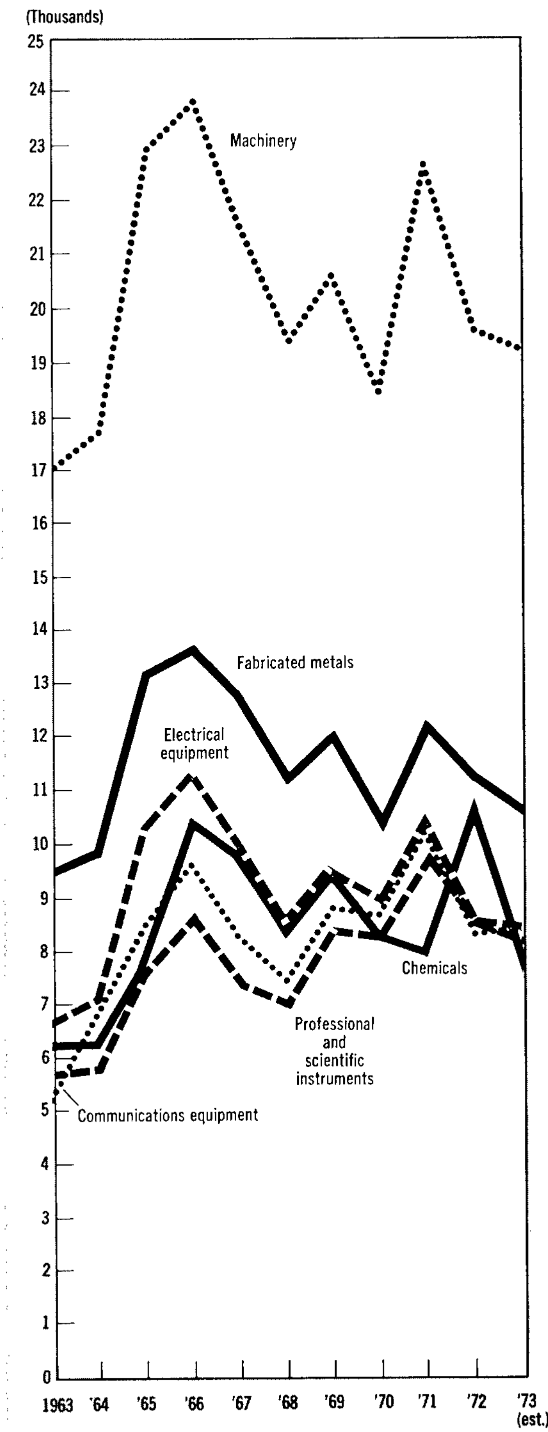
actual number of patents assigned to U.S. corporations increased 73 percent between 1960 and 1973. "Assignment," however, cannot be equated completely with the actual source of the invention. Some patents granted to individuals may be assigned subsequently to corporations, and some patents assigned to the Federal Government have their origins in federally funded R&D performed in industry. Nevertheless, it is clear that industry is the major producer of patented inventions in the U.S.

Patent output by product field. In addition to the sources of patents, information was obtained on the product fields in which the patents were most likely to be applied. Through a concordance developed between the patent classification system of the U.S. Patent Office and the Standard Industrial Classification (SIC)[29] system, it was possible to categorize U.S. patents granted between 1963 and 1973 into 30 SIC-based product fields,[30] with respect to the fields in which the patents were most likely to be applied. These product fields encompass most of the manufacturing sector of industry, and include 96 percent of all U.S. patents granted during the period.

All patents granted to U.S. citizens, corporations, and the Federal Government were assigned to these product fields on the basis of the area of their probable use.[31] The six product fields with the highest patent activity are shown in figure 4-12. The greatest number of patents during the 1963-73 period were applicable to the machinery product field, and within this field to the construction, mining and materials handling machinery subfield. Following machinery in the number of patents were fabricated metals, chemicals (particularly basic industrial chemicals), electrical equipment, communication equipment, and professional and scientific instruments. These fields include many of the areas with a high output of major innovations. (See the later section of this chapter entitled "Technological innovation".)

Figure 4-12

U.S. patents granted for inventions,[1] by selected major product field, 1963-73



[1] Patents originating in the United States.
SOURCE: Office of Technology Assessment and Forecast, U.S. Patent Office.

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[29] *Standard Industrial Classification Manual*, Executive Office of the President, Office of Management and Budget, 1972.

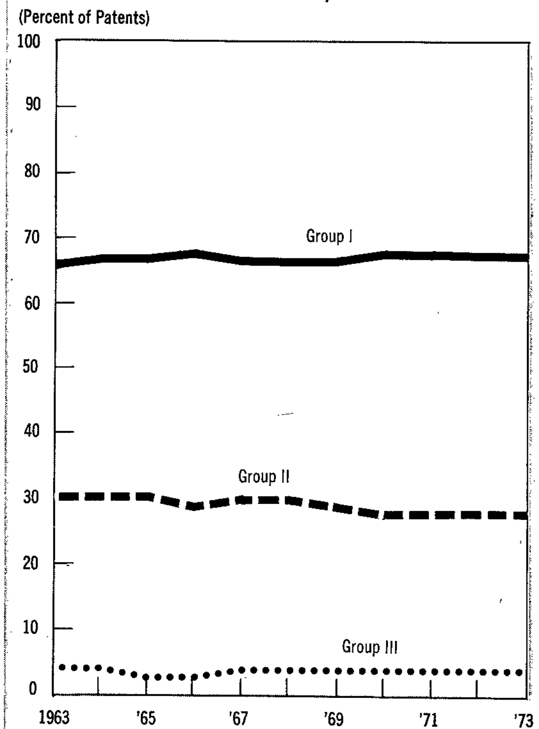
[30] *Indicators of the Patent Output of U.S. Industry*, Office of Technology Assessment and Forecast, U.S. Patent Office, 1974. (A study commissioned specifically for this report).

[31] Because of the possible utilization of the technology represented by a given patent in more than one product field, many patents were counted more than once. For this reason, product field totals do not correspond with the patent totals presented in the previous section.

Patent output by product field and R&D intensity. Patents can also serve as an indicator of the inventive output of specific industries. An approximate correspondence exists between product fields of patent activity and the industries which produce the patented invention. The correspondence is less than perfect, since many companies in a specific industry may be active in a number of diverse product areas. An invention produced by the electrical equipment industry, for example, may have its principal application in the aircraft product field.[32]

The relationship between patent output and R&D intensity is shown in figure 4-13.[33] Those industries which devote the largest proportion of their resources to R&D (Group I industries) are by far the largest producers of patented inventions, accounting for 67 percent of all U.S. patents granted between 1963 and 1973. Group II industries—lower in R&D intensity than Group I—produced about 29 percent of the patents over the period, while the least R&D-intensive industries (Group III) produced only 4 percent.[34] During the same period (1963-73), Group I industries were responsible for 80 percent of the total expenditures for industrial R&D; Group II industries, 16 percent; and Group III industries, 4 percent.

Figure 4-13
U.S. patents granted for inventions in major product fields by groups of R&D-intensive industries, 1963-73



SOURCE: Office of Technology Assessment and Forecast, U.S. Patent Office.

Technological innovation

Technological innovation occurs when new or improved products, processes, or services embodying advances in technology are introduced into the market. Although R&D has a major role in the process, innovation takes place in a broad context in which economic, social, and political factors may be crucial.[35] It has been estimated, for example, that of every ten products emerging from R&D, five fail in product and market tests, and only two become commercial successes.[36]

Technological innovation is integral to the operation of many industries and crucial to their survival and growth. Innovation in these industries may be the principal means for acquiring new markets and maintaining existing ones, as well as for improving internal production processes and reducing costs.[37] Other industries, while producing few major innovations themselves, purchase goods which embody innovations from the first group of

[32] The lack of correspondence, however, was reduced by grouping industries according to their R&D intensity; these groups produced patented inventions which tended to be utilized by industries within the same group.

[33] For a concise review of the relationship between R&D and patents, see Dennis Mueller, "Patents, Research and Development and the Measurement of Inventive Activity," *Journal of Industrial Economics,* Vol. 15 (November 1966).

[34] The patent totals upon which these percentages are based include some multiple counts, but only those which occur across the three groups. The extent of this multiple counting is approximately 8 percent of the total patents granted.

[35] P. Kelly, et al., *Technological Innovation: A Critical Review of Current Knowledge,* (Atlanta: Georgia Institute of Technology, 1975).

[36] E. A. Pessemier, *New Product Decision: An Analytical Approach,* (New York: McGraw-Hill, 1966).

[37] For a review of factors which determine a firm's effectiveness in innovation, see James M. Utterback, "Innovation in Industry and the Diffusion of Technology," *Science,* Vol. 183 (February 15, 1974), pp. 620-626.

industries; these goods may enable the purchasing industries to increase their productivity, improve the quality of their products, or develop new and improved products and services for their own markets. The computer is one of the most obvious examples of an innovation from the first group of industries which is used extensively by other industries.

In addition to its importance at the firm and industry levels, technological innovation is acknowledged as a prime source of the Nation's economic progress, contributing to productivity and economic growth.[38] The capability for such innovation, moreover, is regarded as a major comparative advantage which the United States has in international relations—political, military, and economic.[39]

The present indicators focus on major technological innovations. The vast majority of innovation efforts, however, seek or attain modest improvements in products and processes, rather than major advances. The results of these efforts are not captured by present measures even though the cumulative impact of the more numerous minor advances may often exceed that of major innovations.[40] Furthermore, no indicators are provided of the extent to which the innovations replace or represent advances over existing products and processes. In addition to these limitations, the indicators do not specify the economic and social benefits—and costs—associated with the innovations.

Indicators of trends in innovation presented in this section are based, for the most part, on a study conducted specifically for this report. The study provides information on 500 major product innovations which were introduced into the market during the 1953-73 period by leading industrialized nations.[41] The innovations were selected by an international panel of experts as representing the most significant new industrial products and processes, in terms of their technological importance and economic and social impact.[42] Information on a subset of these innovations—a total of the 319 produced by U.S. industries—was used to develop the measures of innovation presented below. The innovations on which the indicators are based span a wide range of technologies and all major manufacturing and nonmanufacturing industries. The diversity is suggested by the following innovations which were among those included in the study.

- Integrated circuits
- Lasers
- Microwave transmission
- Cortisone synthesis
- Permanent magnetic alloys
- Weather satellites
- Double-knit synthetics
- Computer time-sharing
- Light-emitting diodes
- Textured granular protein

Innovation and company size. A topic of enduring concern is the relationship between size of firm and technological innovation.[43] This topic was examined through the use of the major innovations described above. The results are shown in figure 4-14, in terms of the percentage of innovations produced by companies in each of five size categories. These data, which are based on a total of 277 innovations,[44] show that large manufacturing companies (those with 10,000 or more employees) produced the greatest proportion of major innovations, followed by firms in the two smallest size categories. Companies of intermediate size (1,000-4,999 and 5,000-9,999 employees) accounted for the fewest innovations. The data also show that the number of innovations from large companies has increased over time, in both absolute and relative terms.

Small firms, however, are sometimes regarded as those with less than 1,000 employees. By this

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[38] These aspects are discussed later in this chapter in the section entitled, "Returns from R&D and Innovation."

[39] See the chapter "International Indicators of Science and Technology" in this report for indicators of the role of technology in international trade.

[40] Jacob Schmookler, *Patents, Invention, and Economic Change*, (Cambridge: Harvard University Press, 1972).

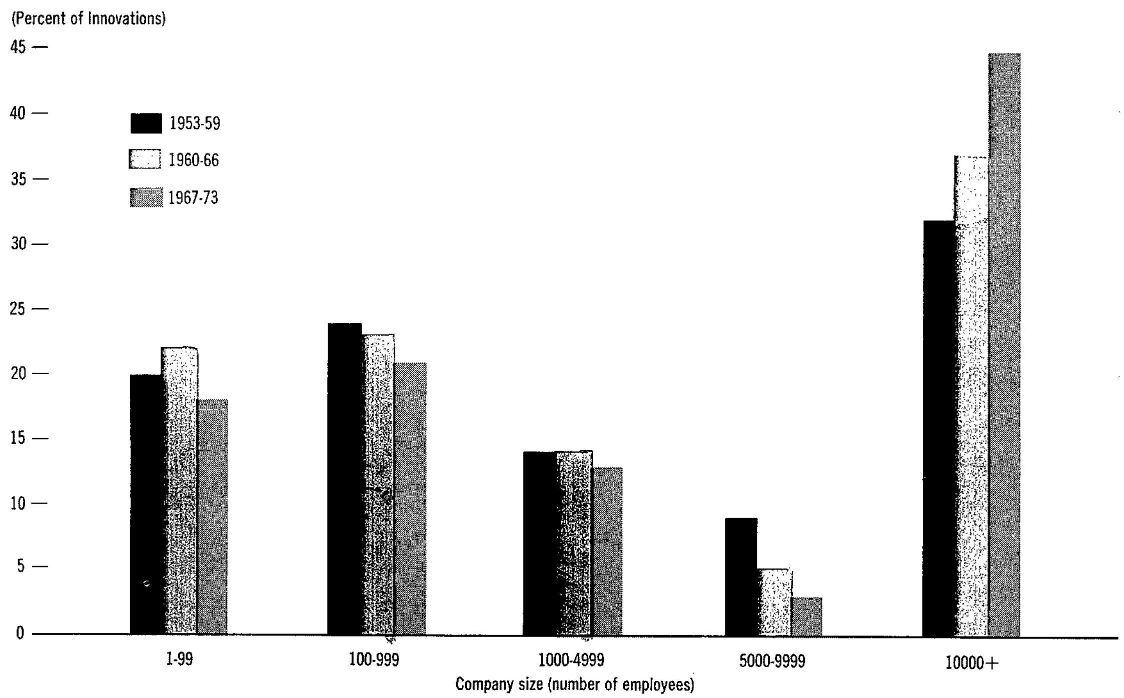
[41] This information was used in devising indicators of the relative innovativeness of the United States and other major developed nations; these indicators are presented in an earlier chapter of this report, entitled "International Indicators of Science and Technology."

[42] For details of the methodology employed in the study, see *Indicators of International Trends in Technological Innovation*, Gellman Research Associates, Inc., 1975. (A study commissioned specifically for this report).

[43] For a discussion of factors related to firm size which may influence innovation, see Sumner Myers and Donald G. Marquis, *Successful Industrial Innovations, A Study of Factors Underlying Innovation in Selected Firms*, National Science Foundation (NSF 69-17).

[44] Here, and elsewhere, the number of innovations used for analysis may be less than the total 319 innovations mentioned earlier because of the unavailability of specific data on all the innovations, or the consideration of only those originating from manufacturing industries.

Figure 4-14
Distribution of major U.S. innovations, by size of company, 1953-73



SOURCE: Gellman Research Associates, Inc.

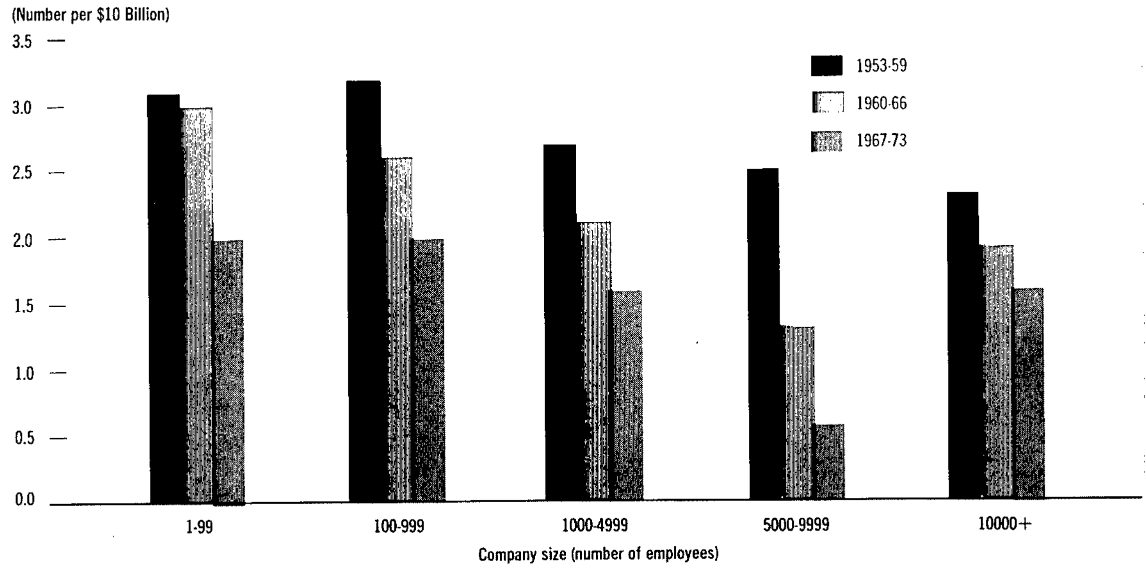
definition, the small firm—rather than the large one—was the site of the greatest number of major innovations during the 1953-59 and 1960-66 periods, but not in the 1967-73 period.

The matter of firm size and innovation can be viewed also with respect to the sales volume associated with companies of different size. When this aspect is considered, the smallest companies are found to produce proportionally more innovations per unit sales than larger companies (figure 4-15). Small firms, furthermore, have maintained a relatively higher level of innovative output per unit sales than larger companies in each of the time periods for which sales data are available.[45] (The decline in the number of innovations per unit sales, observed in each company size category, results from a combination of increasing company sales and a relatively constant number of innovations.)

These indicators shed some additional light on the question of the relationship between firm size and technological innovation. The indicators, however, are dependent on the particular set of innovations selected for study. Furthermore, all industries are treated as if they were alike, even though differences among them with respect to innovativeness may exceed the differences between small and large firms. Finally, the indicators offer no insights regarding the attributes, causal factors, and dynamics which determine the relative innovativeness of various size companies. For these and other reasons, interpretations of indicators presented here should be limited and tentative.

[45] Data on sales and receipts of manufacturing industries, in terms of company size, are available only for the years 1958, 1963 and 1967 and are taken from *Enterprise Statistics*, Department of Commerce, Bureau of the Census, 1968 and 1972.

Figure 4-15
Major U.S. innovations per $10 billion in sales, by size of company, 1953-73



SOURCE: Gellman Research Associates, Inc., and Department of Commerce.

Innovation and R&D intensity. The most R&D-intensive industries (Group I industries) produced the largest fraction of the major U.S. innovations in the manufacturing sector—182 of the 277 innovations included in this analysis—during the 1953-73 period, followed by innovations from industries in Groups II and III (figure 4-16). Innovations by Group I industries comprised 66 percent of the total, compared with 24 percent in Group II and 10 percent in Group III industries.

Group I industries accounted for 80 percent of the total industrial R&D expenditures over roughly the same period (1956-73), compared to 16 percent from Group II, and 4 percent from Group III. Over the 1953-73 period as a whole, the number of innovations from the most R&D-intensive industries increased to a greater extent than those from the other two industrial groups. After the 1965-68 period, however, the number of innovations in Group I industries declined in relative terms.

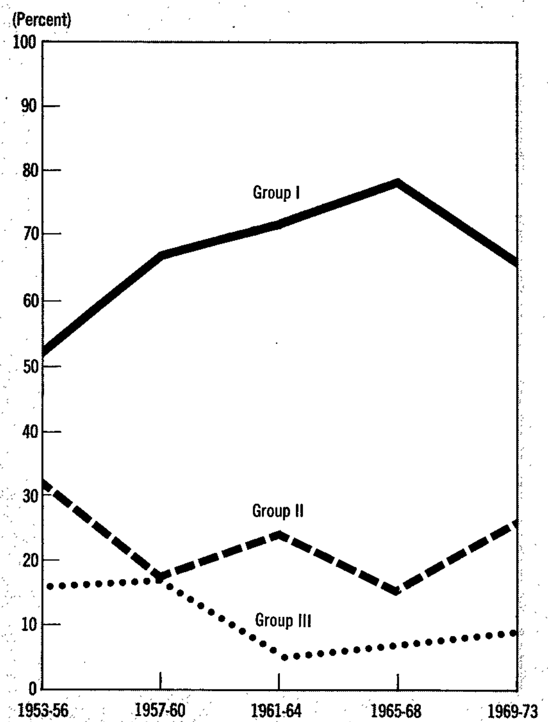
Within these industry groups, the largest number of innovations—171—are in four of the most R&D-intensive industries: electrical equipment and communication; chemicals and allied products; machinery; and professional and scientific instruments (figure 4-17).[46] It should be noted that innovations in the defense and space areas are not included unless they were introduced into the commercial market; this may account, at least in part, for the relatively small number of innovations from the fifth Group I industry—aircraft and missiles.

Innovations in the manufacturing sector were examined to identify the major areas of innovative activity and the shifts among these areas during the 1953-73 period. For this purpose, innovations were classified in terms of their product fields through use of the Standard Industrial Classification (SIC). The product fields with the largest number of innovations are listed below for each of three time periods. The fields are described briefly in terms of their corresponding three-digit SIC designations, and ranked in approximate order of the number of associated innovations.

[46] See Appendix table 4-17 for the number of major innovations in each of the 15 manufacturing industries.

Figure 4-16

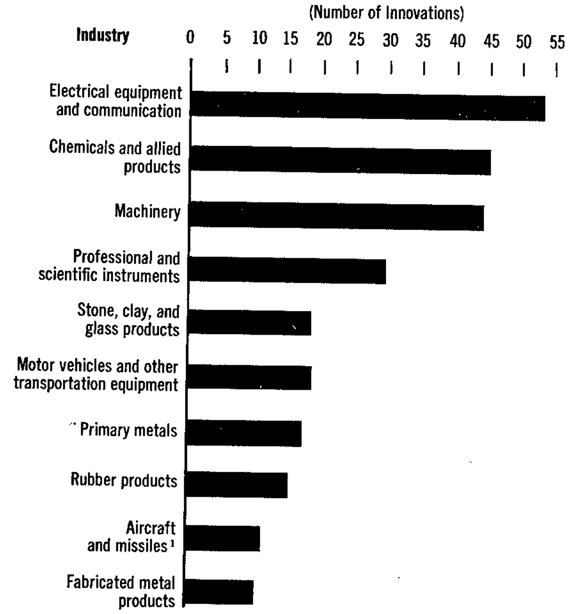
Percent distribution of major U.S. innovations, by groups of R&D intensive industries, 1953-73



SOURCE: Gellman Research Associates, Inc.

Figure 4-17

Major U.S. innovations in selected industries, 1953-73



[1] Innovations in the defense and space areas are not included unless they were introduced into the commercial market.
SOURCE: Gellman Research Associates, Inc.

1953-59

Medicinal chemicals & pharmaceutical products
Industrial organic chemicals
Electronic components and accessories
Electronic calculating and computing machinery
Metalworking machinery and equipment
Machinery for specific industries
Photographic equipment and supplies

1960-66

Electronic components and accessories
Communications equipment
Electronic calculating and computing machinery
Synthetic materials
Plastic films, sheets, and cellulose products
Medical instruments and supplies
Abrasives, asbestos & nonmetallic mineral products

1967-73

Electronic components and accessories
Photographic equipment and supplies
Motor vehicles and other transportation equipment
Machinery for specific industries
Abrasives, asbestos & nonmetallic mineral products
Communications equipment
Synthetic materials

The prominent role of electronics is evident in each of the three periods, particularly during the early 1960's. The relatively large number of innovations in this area is due, in part, to significant advances in scientific knowledge in fields closely related to electronics.[47] In-

[47] Richard R. Nelson, et al., *Technology, Economic Growth, and Public Policy*, (Washington, D.C.: The Brookings Institution, 1967).

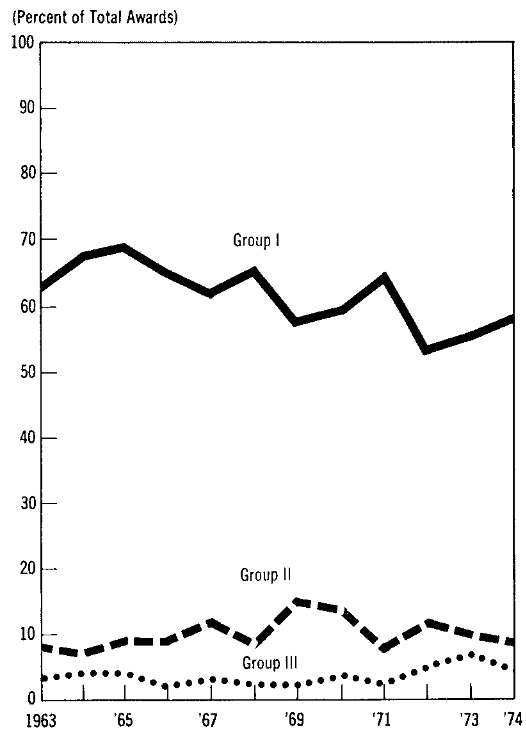
novations in product fields associated with chemicals appear to have declined somewhat since the 1950's.

Another set of technological innovations was used in developing an additional indicator for this report.[48] This set consisted of "IR-100" award winners, one hundred of which are selected annually by the Editorial Advisory Board of *Industrial Research* magazine. The awards, begun in 1963, identify significant technological advances and recognize innovators and organizations responsible for such developments. The innovations are selected on the basis of their importance, uniqueness, and usefulness from a technical standpoint. They are chosen, in general, from advances in technology which have particular interest for the industrial research community; for this reason, the innovations tend to concentrate in areas such as scientific instruments, electronic apparatus, and new industrial materials. The innovations, therefore, represent a somewhat limited segment of the total U.S. innovation activity, and do not reflect market success nor economic impact.

Each of the more than 1,200 "IR-100" award-winning innovations chosen over the 1963-74 period was classified according to the SIC designation of the industry of origin and grouped in terms of its industry's R&D intensity. Over 75 percent of the innovations were found to originate in industries included in the three groups of R&D-intensive industries. (The remainder originated primarily in nonmanufacturing industries, academic institutions, or U.S. Government agencies.) As shown in figure 4-18, the most R&D-intensive industries (those of Group I) were responsible for the largest share of innovations over the twelve year period, accounting for about 62 percent of all the "IR-100" awards. Industries in Group II claimed approximately 10 percent and Group III industries some 4 percent of the total innovations. The preponderance of innovations in Group I results primarily from the large number of innovations originating in the electrical equipment and communications industry and the professional and scientific instruments industry. Together, these two industries accounted for over 45 percent of all the "IR-100" awards given over the twelve year period.

Figure 4-18

"IR-100" award-winning innovations[1], by groups of R&D-intensive industries, 1963-74



[1] Industrial Research magazine's annual awards for the 100 "most significant new technological products of the year."

SOURCE: Battelle Columbus Laboratories.

Time between invention and innovation. The innovation process—extending from the "first conception" of the innovation to "first realization"—may cover a long period of time. This interval may be necessary, among other things, to conduct research, determine the technical feasibility of the potential innovation, design and test engineering prototypes, develop the required manufacturing capability, and perform market analyses. The period is difficult to define precisely, since invention and innovation usually occur as stages in the process, rather than as discrete events. Roughly, invention occurs when initial determination of the technical feasibility of a new idea is made, while innovation corresponds to the actual commercial development and marketing of the new product or process. The invention-innovation intervals are approximate, and are usually not strictly comparable from one study to the next.

[48] *Indicators of the Output of New Technological Products from Industry*, Battelle Columbus Laboratories, 1975. (A study commissioned specifically for this report).

In a study of a selected number of major innovations,[49] the interval between invention and innovation appeared to decrease over time, as suggested by the following gross historical trends.[50]

Average time between invention and innovation

Time period	Years
Early 20th century (1885-1919)	37
Post-World War I (1920-1944)	24
Post-World War II (1945-1964)	14

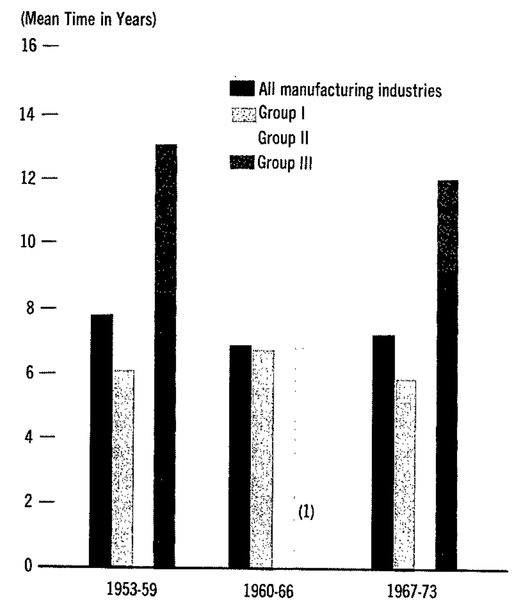
It is generally advantageous for an industrial firm to minimize the time between invention (i.e., the first conception of an innovation) and its introduction into the market. Competing firms may introduce similar products earlier, giving them a favored position in the market; the cost of capital may increase; or a loss in sales and profits may be experienced due to a lag in the introduction of innovations into the market. These and other considerations usually encourage rapid innovation in order to reduce risk and increase profitability.

Trends in the time between invention and innovation were calculated from a set of 277 innovations[51] associated with the three groups of manufacturing industries which varied in respect to R&D intensity. The invention-innovation intervals, which ranged from less than one year to 82 years, were determined for each industry group and for all manufacturing industries combined. The results are shown in figure 4-19 in terms of the mean number of years between invention and innovation for three time periods between 1953 and 1973.

These data suggest that the invention-innovation interval was shorter in recent years (7.2 years during the 1967-73 period) than in the 1950's (7.8 years), but generally somewhat longer than in the early 1960's (6.9 years).[52] [53] Furthermore, the time between invention and innovation appears to correlate with R&D intensity. Industries with the largest fraction of financial and human resources for R&D tend to translate inventions into innovations more quickly than industries which are less R&D-intensive. In each of the three periods, the mean invention-innovation interval for industries of Group I was shorter than the interval for Group II which, in turn, was shorter than that for Group III industries.

Figure 4-19

Mean time in years between invention and innovation, by groups of R&D-intensive industries, 1953-73



[1] Insufficient number of innovations for determining mean of Group III industries.

SOURCE: Gellman Research Associates, Inc.

[49] Frank Lynn, "An Investigation of the Rate of Development and Diffusion of Technology in Our Modern Industrial Society", *Report of the National Commission on Technology, Automation, and Economic Progress*, 1966.

[50] For other studies of the invention-innovation interval, see Edwin Mansfield, *The Economics of Technological Change*, (New York: W. W. Norton, 1968), and *Interactions of Science and Technology in the Innovative Process: Some Case Studies*, Battelle Columbus Laboratories for the National Science Foundation, March 1973.

[51] The 277 U.S. innovations are among those identified in *Indicators of International Trends in Technological Innovation*, Gellman Research Associates, 1975.

[52] It has been suggested that the actions of Federal regulatory agencies may be responsible, in part, for the lengthening of the invention-innovation interval in recent years.

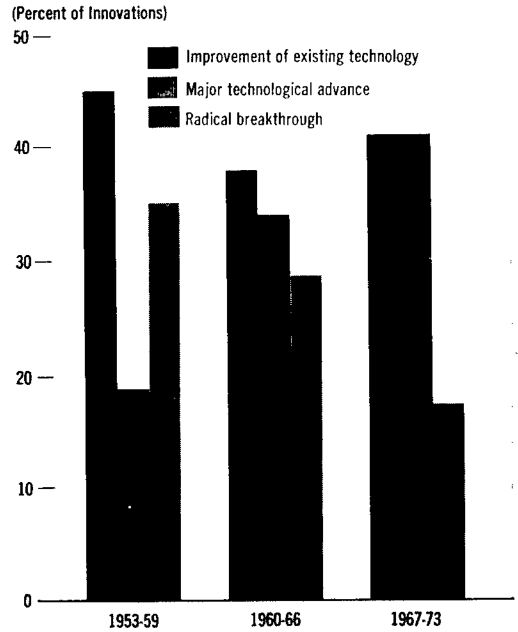
[53] These data differ from those presented for the U.S. in the chapter, "International Indicators of Science and Technology"; the invention-innovation intervals in that chapter are based upon all industries rather than the smaller set of selected manufacturing industries encompassed in this section.

"Radicalness" of the innovations. Innovations may range from imitations of existing technologies to developments of radically new technologies and products. At one end of the spectrum, little or no new knowledge may be involved in an innovation, while at the other end, new and fundamental advances in knowledge may constitute the basis for the innovation. The distribution of innovations along this spectrum was estimated by obtaining ratings of the "radicalness" of the innovations. These ratings were made by the innovating organizations themselves. Although inherently subjective, such ratings may provide some valid insights regarding trends in industrial innovation.

Each innovation was assigned to one of five categories which together form the "radicalness" continuum: "no new knowledge required", "imitation of existing technology", "improvement of existing technology", "major technological advance", and "radical breakthrough".[54] Of the 225 innovations for which ratings were obtained, only 17 were rated in the first two categories; these innovations were omitted in subsequent analyses. Included among the innovations rated as radical were integrated circuits, permanent magnetic alloys, and L-Dopa, which is used in the treatment of Parkinson's disease. Innovations regarded as representing major technological advances included hand-held solid state calculators, Ketalor (an anesthetic), and an ultrasonic process for the joining of synthetic fibers. Improvement of existing technology was represented by such innovations as a high-speed phototypesetting machine, resin catalysts, and Pyroceram, a hard, light-weight, and heat-resistant material.

Innovations involving the improvement of existing technology were most prevalent, followed in order by those which constitute a major technological advance and the set which represents radical breakthroughs (figure 4-20). Over the 1953-73 period as a whole, 41 percent of the 208 innovations included in the analysis were rated as improvements in existing technology, compared with 32 percent in the category of major technological advance and 27 percent in the radical class. The most significant change in this distribution during the period centered on the latter two categories. The number of innovations rated as radical breakthroughs declined nearly 50 percent between 1953-59 and 1967-73, while the number representing major technological advances doubled during the same period. As a result of these changes, radical innovations accounted for 18 percent of the innovations in the 1967-73 period, down from 35 percent in 1953-59.

Figure 4-20
"Radicalness" of major U.S. innovations, 1953-73



SOURCE: Gellman Research Associates, Inc.

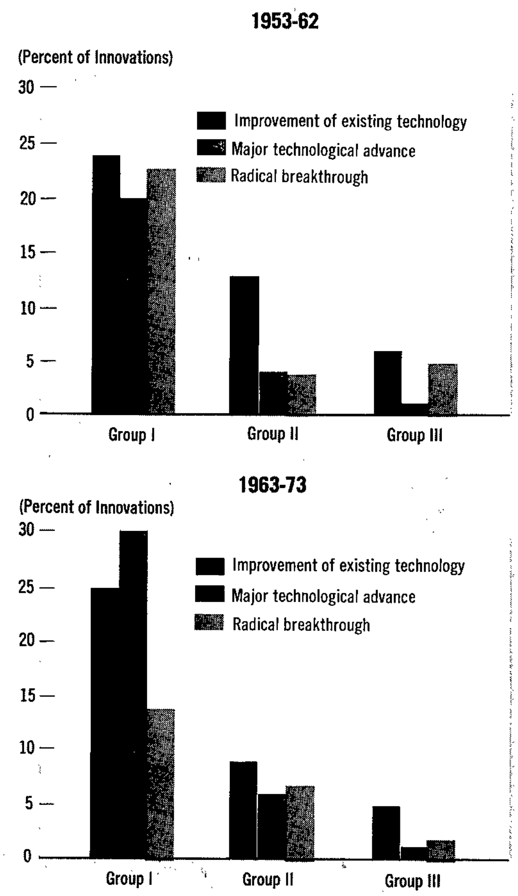
The overall decline in radical innovations (and the corresponding increase in innovations representing a major technological advance) is due primarily to reductions in the number of such innovations from the most R&D-intensive industries (figure 4-21). Radical innovations in these industries decreased from 23 percent of the innovations in 1953-62 to 14 percent in 1963-73, whereas the proportion involving major technological advances rose from 20 percent to 30 percent over the same periods.

Research and innovation. The technology embodied in an industrial innovation may be

[54] The "radicalness" of innovations, it may be noted, does not determine their economic or social significance. Innovations which represent improvements or even imitations of existing technologies may have greater economic returns or social consequences than more radical innovations.

Figure 4-21

"Radicalness" of major U.S. innovations, by groups of R&D-intensive industries, 1953-62 and 1963-73



SOURCE: Gellman Research Associates, Inc.

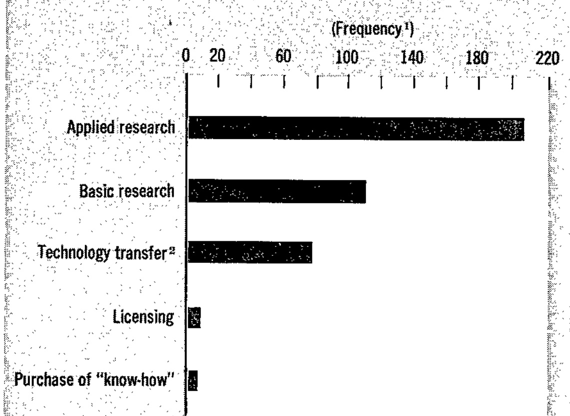
obtained through a variety of means. These include basic research, applied research, licensing, merger or acquisition of other concerns, and the transfer of technology from another product line. Various combinations of these means may be involved in the case of a single innovation. For example, the underlying technology for the light-emitting diode was acquired through a combination of internally generated basic and applied research, coupled with the transfer of technology from one of the firm's existing product lines.

The modes by which the technology was acquired for the innovations in this study are shown in figure 4-22. These data, supplied by the innovating firms, represent the number of innovations in which the various acquisition modes were involved. Each mode is counted separately, even if the underlying technology involved a combination of sources; and each mode, and all instances of its occurrence, are treated as equally important in the innovation process. It should be noted also that the information collected regarding the underlying technology applies only to the period between conception and realization of the innovation and does not include prior research activities. These several limitations require that the indicators be regarded as gross measures only.

The dependence of innovation on research[55]—applied and basic—is evident from figure 4-22; applied research was involved in almost 75 percent of the innovations, and basic research in almost 40 percent. Aside from research, the only other acquisition mode of significance was the transfer of technology from existing product lines. Actually, research is involved even more extensively in innovation than the figure

Figure 4-22

Sources of technology underlying major U.S. innovations, 1953-73



[1] Multiple responses were accepted.
[2] From within the innovating company.
SOURCE: Gellman Research Associates, Inc.

[55] See the chapter in this report entitled "Basic Research" for additional information on the relationship between research and innovation.

suggests. First, much of the transferred technology itself is based on prior research. But even more important is the contribution from the total body of knowledge gained from centuries of scientific research—knowledge upon which innovation in general draws.

The research directly underlying the innovations was reported by the firms to have been performed primarily by the innovating companies themselves. This was particularly true for applied research, but significantly less so for basic research. In some 96 percent of the cases, applied research was performed within the innovating firm, compared with 73 percent for basic research. Although no attempt was made to determine where the external portion of the basic research was performed, it may be presumed to have been performed largely in the university sector. As indicated in the "Basic Research" chapter of this report, industrial innovation (as represented by major patented technological advances) depends heavily upon basic research performed in universities—a dependency which has increased over the years.

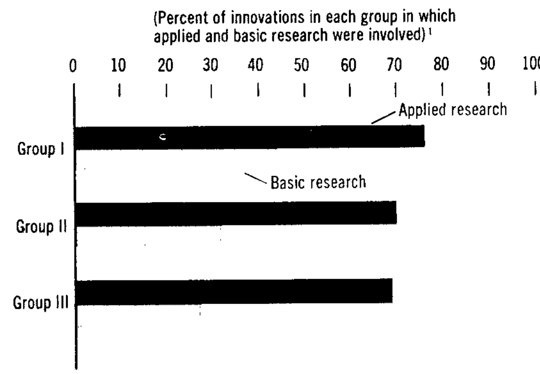
Research figures prominently in the sampled innovations of all industries, the least R&D-intensive as well as the most intensive (figure 4-23). Applied research was involved in some 70 percent of the innovations in each of the three groups of industries (Groups I, II, and III) which vary from high to low in their R&D intensiveness. Basic research, on the other hand, was more frequently associated with the innovations of Group I industries than with those of Groups II and III—44 percent versus 32 and 28 percent, respectively.[56]

A similar pattern of dependency was found between research and the "radicalness" of innovations (figure 4-24). Applied research was reported with nearly equal frequency for innovations representing radical breakthroughs, major technological advances, and improvements in existing technologies. Basic research, however, was more often involved in innovations characterized as radical breakthroughs than it was in the other two categories. Such research was reported as a source of innovation in 68 percent of the new products and processes regarded as radical innovations, compared with less than 50 percent in the case of other innovations.

[56] The percentages reported in this section are based on the innovations within each group of R&D-intensive industries.

Figure 4-23

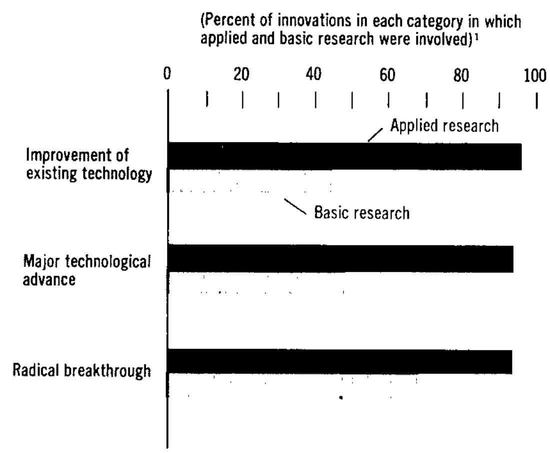
Research underlying major U.S. innovations, by groups of R&D intensive industries, 1953-73



[1] Multiple responses were accepted.
SOURCE: Gellman Research Associates, Inc.

Figure 4-24

Research underlying major U.S. innovations and "radicalness" of innovations, 1953-73



[1] Multiple responses were accepted.
SOURCE: Gellman Research Associates, Inc.

The U.S. innovations included in the study conducted by Gellman Research Associates, Inc., were examined to identify the more specific fields of science which had contributed in a major way to the realization of these innovations. These fields are listed below, along with the principal industries and product areas to which the fields contributed most directly. Associated with each field is a sample of the innovations in which the specific field played a significant role.

Scientific field	Industries and products	Illustrative innovations
Polymer chemistry	Chemicals and allied products Plastic materials and synthetic resins Industrial organic chemicals Rubber and miscellaneous plastics products	acrylic adhesives double-knit synthetics polyoryl ether phenolic adhesives epoxy cement
Atomic electron and molecular physics	Electrical and electronic machinery and equipment Communication equipment and services Electronic components and accessories Electrical industrial apparatus Machinery Office, computing, and accounting machines Special industrial machinery Professional and scientific instruments	microwave transmission lasers weather satellites magnetic computer cores video tape
Metallurgy	Primary metals Fabricated metal products Machinery Transportation equipment	permanent magnetic alloys transparent stainless steel superconducting magnets Niobium Beryllium
Inorganic chemistry	Chemicals and allied products Industrial inorganic chemicals Stone, clay, glass, and concrete products Electrical and electronic machinery and equipment Electrical industrial apparatus	Borazon oil slick emulsifiers synthetic cryolite Pyroceram synthetic diamonds
Optics	Professional and scientific instruments Optical instruments and lenses Surgical, medical, and dental instruments Photographic equipment and supplies Electrical and electronic machinery and equipment Electronic components and accessories	optical scanners Polaroid camera holography via laser fiber optics
Organic chemistry	Chemicals and allied products Industrial organic chemicals Agricultural chemicals Drugs and medicines Food and kindred products	liquid chromatography textured granular protein benzene—phenol process phenyldimethylurea (herbicide)
Solid-state physics	Electrical and electronic machinery and equipment Electronic components and accessories Communication equipment and services Electrical industrial apparatus Machinery Office, computing, and accounting machines Professional and scientific instruments	light-emitting diodes minicomputers printed circuits integrated circuits silicon-controlled rectifiers
Acoustics	Machinery Special industrial machinery Office, computing, and accounting machines Electrical and electronic machinery and equipment Electronic components Communication equipment and services Professional and scientific instruments	long range sonar Xerox Telecopier II sonic pile drivers ultrasonic sealers acoustic couplers (telephone-computer)
Biology and bioengineering	Professional and scientific instruments Surgical, medical, and dental instruments Electrical and electronic machinery and equipment	kidney transplants heart pacemakers muscle-activated prosthetics surgery by laser
Pharmacology	Drugs and medicines	Ketalar (anesthetic) L-Dopa (Parkinson's disease) Terramycin cortisone synthesis

Virtually all major fields of science contribute to technological innovation, but certain fields are particularly significant, as indicated in the table above. The physical sciences (especially chemistry and physics) are of general importance across the entire spectrum of industrial innovation. The significance of the biological sciences and medicine has increased considerably in the last decade, both in their direct and indirect contributions to innovation.

RETURNS FROM R&D AND INNOVATION

The contribution of R&D and innovation to the economy and society is presently understood in broad and general terms only. Existing knowledge of the subject is fragmented and tenuous, to an extent which prohibits the development of indicators of the kind presented elsewhere in this report. Several studies, however, have been conducted in the area, particularly in the last decade. Some of the major findings of these studies are summarized below in the form of tentative conclusions based upon the collective results of these investigations.

The findings from the various studies, including estimated rate of returns from investment in R&D and innovation, are not strictly comparable. The studies employ different concepts, assumptions, and methodologies; each has limitations regarding the specification of inputs, the level of aggregation and the availability of data, and the method and degree of attribution of calculated outputs. They, in addition, have one major limitation in common—the inability of conventional measures (such as the Gross National Product and output per man-hour) to capture the full impact of technological innovation on the economy and on society. For these and other reasons of a methodological nature, findings regarding the contributions and returns from R&D and innovation appear to be underestimated in general **(1)**.[57]

The contribution of R&D to economic growth and productivity is "positive, significant, and high" **(2)**. This contribution occurs through technological innovation consisting of enhanced production processes and new and improved products and services. These may expand economic output, increase productivity, or reduce unit costs. Such innovation is regarded as an important—possibly the most important—factor in the economic growth of the United States in this century **(3-5)**.

Investment in R&D and innovation yields a rate of return as high—and often higher—than the return from other investments. This applies to investments for specific innovations by both the public and private sectors and to R&D investments by individual industries. Rates of return from specific innovations are estimated, conservatively, to average between 10 and 50 percent per year **(6-11)**, while returns to innovating industries in the form of productivity growth range from 30 to 50 percent **(12-21)**.

The benefits to industries which purchase new and improved products from innovating firms may equal or exceed the direct returns to the innovating firms themselves. These benefits occur particularly in the form of reduced costs or prices per unit of output in the industries which purchase and use the innovations. The rate of return to these industries is estimated to range from 20 to 80 percent per year **(22-24)**.

Industry may underinvest in R&D and innovation with respect to the probable returns to the firm and the benefits to society **(25-27)**. Firms may invest less than the average returns to them would warrant because of the uncertainty and risk associated with specific innovation efforts, as well as the lengthy time before returns can be expected, and the scale of investment which is often involved in innovation. Although the potential benefits to society may often exceed the cost of innovation, a firm may not be able to translate enough of these benefits into profits to justify the necessary investment. "This is particularly true of basic research, where the output frequently occurs. . . not as a marketable product but rather as an advance in basic knowledge that can subsequently be used in applied research and development by a wide and often unforeseeable range of firms" **(27)**.

Standard indices of economic performance reflect only part of the contribution which R&D and innovation make to the economy and society **(28)**. Technological innovation sometimes results in new products (e.g., antibiotics and the airplane) which satisfy material needs and wants not satisfied previously. The value of such innovations may far exceed the price paid for the products, although only the latter is counted in standard economic measures. In addition, the effects of qualitative improvements in products and services (e.g.,

[57] These numbers refer to the references provided at the end of this chapter.

machinery requiring less maintenance or longer-lasting automobile tires) may not be represented adequately in common economic indices. In fact, innovations of this kind may contribute less to economic growth as commonly measured than was contributed by the unimproved products. Finally, in present economic accounting, goods and services provided to the public sector through nonmarket channels are valued at cost, rather than at market prices. Thus, benefits from R&D and innovation in areas such as public education and national defense may be underestimated by a considerable margin in conventional economic indices.

While the benefits from innovation are only partially accounted for by economic indicators, little if any of the associated societal costs are reflected. These costs in human and social terms, as discussed earlier in this chapter, may be substantial, especially when the full range of adverse effects such as loss of jobs and potential health hazards are considered.

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Science and Engineering Personnel

Science and Engineering Personnel

INDICATOR HIGHLIGHTS

- The total number of scientists and engineers employed in these occupations in 1974 was approximately 1.7 million, which is nearly the same as in 1970, with engineers representing nearly two-thirds of the total.
- The number of scientists and engineers with doctorates reached approximately 245,000 in 1973, representing almost 15 percent of all scientists and engineers; life and physical scientists each accounted for one-fourth of the doctoral total.
- The majority of doctoral scientists in 1973 were employed in educational institutions (64 percent), and primarily engaged in teaching, while doctoral engineers tended to be concentrated in business and industry (49 percent) and were primarily involved in R&D.
- Employment of scientists and engineers in universities and colleges increased between 1965 and 1974 by more than 60 percent, with most of the growth occurring prior to 1972; the largest increases in employment occurred for life and social scientists, bringing the total number of scientists and engineers employed in higher education to just over 288,000 in 1974.
- In recent years the proportion of young doctoral faculty in doctorate-level science and engineering departments has declined from approximately 42 percent in 1968 to some 28 percent in 1974; concurrently, median ages have increased from 41 to 44 years, and the proportion of faculty with tenure has risen from 47 percent to 65 percent.
- The largest number of the Nation's scientists and engineers were employed in industry, with engineers accounting for nearly 80 percent of the total in 1974; approximately 25 percent of the engineers were involved in R&D and its management, compared with some 35 percent of the industrial scientists.
- The Federal Government supported less than one-fourth of all industrial scientists and engineers in 1974, down from nearly 30 percent in 1972; most of the support was provided by DOD and NASA which together accounted for nearly 70 percent of all such Federal support.
- The number of scientists and engineers employed by the Federal Government declined in 1973 for the first time since the 1950's; employment in this sector comprised 10 percent of all employed scientists and engineers in 1973, with some 30 percent of the Federal total involved in R&D.
- The total number of scientists and engineers engaged in R&D (on a full-time equivalent basis) was 530,000 in 1974, down by more than 30,000 from the high in 1969; 68 percent of the total were employed in industry, 13 percent in the academic sector, and 12 percent in the Federal Government.
- Approximately 40 percent of all doctoral scientists and engineers were involved in R&D in 1973; in universities, physical and life scientists comprised the majority of doctorates who were involved primarily in basic and applied research; in the industrial sector, most doctorates were engineers working on development-related activities.
- The number of R&D scientists and engineers in industry increased in 1973 and 1974, reaching almost 360,000 (on a full-time equivalent basis) but nearly 7 percent less than the number employed in the peak year of 1969; the decline occurred primarily in the aircraft and missiles industry, and was confined mainly to those scientists and engineers supported by Federal funds.
- Academic R&D was conducted by 67,000 scientists and engineers (on a full-time equivalent basis) in 1973, and was heavily focused on research (basic and applied). Of all the doctoral faculty involved in R&D, the proportion of young investigators decreased

for all science and engineering fields by 14 percent between 1968 and 1974.

- Annual awards of bachelor's and first-professional degrees in the sciences and engineering doubled between 1963 and 1972; as a fraction of first degrees awarded in all fields, however, those in science and engineering remained essentially constant at nearly 30 percent during the period, due in large part to a rapid growth in the number of social science degrees awarded. Awards of master's level degrees in science and engineering followed a similar trend, but declined in recent years to 21 percent of all master's degrees awarded.

- Annual awards of doctoral degrees in science and engineering began to level off in 1971, decreasing for the first time in a decade to a level in 1974 of approximately 18,000; the largest declines occurred in the number of physical science doctorates awarded; science and engineering doctorates as a fraction of all doctorates declined from 64 percent in 1965 to 56 percent in 1974.

- The proportion of science and engineering graduate students receiving Federal support declined from 42 percent in 1967 to 25 percent in 1974; this decrease was compensated primarily by increases in self-support (up 13 percent) and institutional support (up 6 percent).

- Women comprised 5 percent of the persons employed in science and engineering occupations in 1974, and were primarily involved in psychology, social sciences, and mathematics; in the academic sector, women represented 15 percent of all scientists and engineers employed full-time in 1974.

- The predominant proportion of all scientists and engineers in 1972 were Caucasian (96 percent), while 2 percent were Asian, and 1 percent each were Black or were of other nonwhite background; the smallest proportional representation of minorities is in engineering (3 percent) and the largest is in mathematics (8 percent).

The country's scientists and engineers are an important national asset. They provide instruction and training in the various fields of science and engineering, conduct basic research to advance the understanding of nature, and perform applied research and development in a diversity of areas such as health, defense, energy, and industrial technology. In addition, persons trained in the sciences and engineering are employed throughout the economy—from industrial management to agricultural production—to provide the knowledge and skills which are essential in a technologically advanced society. The role of scientists and engineers in helping to meet the changing needs of the Nation, coupled with the extended time and high cost involved in their training, requires that continuous attention be given to trends and patterns in the production and utilization of such personnel.

This chapter presents information on the magnitude and characteristics of the Nation's population of scientists and engineers. It considers trends in the supply and utilization of these personnel and examines developments which may affect their future supply.

Scientists and engineers, in this chapter, are defined as persons actually engaged in scientific or engineering work at a level which requires knowledge of the physical, life, social, mathematical, or engineering sciences equivalent at least to that acquired through completion of a four-year college program with a major in one of these fields, regardless of whether a college degree is actually obtained in the field. In regard to data presented on employment, enrollments, and degrees awarded, the health professions are not included under "science and engineering", unless otherwise indicated.

Throughout the chapter, information is limited to certain quantitative aspects of scientists and engineers. These measures, it is recognized, provide only a partial indication of the characteristics of such personnel. Lacking are measures of the quality of their work, extent of "underutilization", and the increasingly important concerns of productivity and output. Furthermore, little is known about motivational factors that affect the supply and utilization of scientists and engineers, such as considerations which lead students to enter science and

engineering, or influence those already in these fields to move from one type of employment to another. The present lack of such indicators, it is hoped, will be remedied in the future as improved methodologies are developed for measuring these aspects.

The measures of quantitative characteristics presented here are themselves less than complete.[1] In the case of the utilization of scientists and engineers, for example, data are not available after 1970 with respect to industrial employment. Data are also lacking on new baccalaureates and masters entering the market since 1970. Information on the specific activities of scientists and engineers, especially those in the academic sector, are limited by the current inability to obtain full-time equivalent (FTE) data on major activities such as R&D and teaching, by field of science. The surrogate measure of numbers of scientists and engineers "primarily involved" in an activity provides a useful but relatively crude measure of this factor. In the case of supply, the latest data on the production of baccalaureate and masters degrees from the National Center for Educational Statistics covers the 1972-73 period.

CHARACTERISTICS AND UTILIZATION OF SCIENCE AND ENGINEERING PERSONNEL

Employment of scientists and engineers

Employment of scientists and engineers stabilized in the first years of the 1970's, after increasing substantially for several decades.[2] During the 1950's, the number of scientists and engineers doubled, rising from about 600,000 to nearly 1.2 million. In the 1960's, employment grew by almost as much in absolute terms, from about 1.2 to over 1.7 million; the relative gain, however, was only about half that of the 1950-60 decade. Furthermore, between 1960 and 1970 the number of scientists grew significantly faster than the number of engineers (75 and 38 percent respectively), partially as a result of substantial gains in social science fields.

[1] Some of these deficiencies are expected to be corrected during the next year through the new National Science Foundation—Bureau of the Census surveys of industrial employment and the complete implementation of the National Science Foundation Manpower Characteristics System.

[2] *Employment of Scientists and Engineers, 1950-70*, Bureau of Labor Statistics, Department of Labor, 1973.

Beginning in 1969, growth in total employment of scientists and engineers slowed and then remained relatively level until about mid-1972. The factors underlying these changes include cutbacks in defense, space, and associated R&D spending in these areas, the general economic climate, and the beginning of a slowdown in academic hiring. Though employment in some sectors continued to increase—namely, higher education and government (particularly State and local)—little if any growth occurred in industry, the major sector of employment for scientists and engineers. Unfortunately, no specific measurements of industrial employment of scientific and technical personnel have been taken since 1970, though a survey is being reinstated by the National Science Foundation. However, by using information on past trends and relationships and several related sources of information, it has been possible to prepare estimates of the probable level of industrial employment of scientists and engineers for 1972. Using these estimates, together with information on nonindustrial sectors of employment, it is thus possible to estimate the total number of scientists and engineers employed in 1972. The available data do not permit estimates to be made for more recent years.

In 1972, estimated overall employment of scientists and engineers stood at about 1.7 million, approximately the same as in 1970. In the first years of the 1970's, employment in the sciences continued to grow slightly while engineering employment declined somewhat between 1970 and 1972. These overall patterns of change include minor shifts in the sectoral distribution, with university and college and Government employment gaining while the proportion declined for the industrial sector.

Although recent information is not available on an overall and detailed basis for scientists and engineers, selected information about such personnel is provided by the National Science Foundation's National Sample of individuals in science and engineering jobs. A sample was drawn from the 1970 Census of Population and used for the 1972 and 1974 surveys; the results provide information on a large portion of the Nation's science and engineering personnel.

An estimate of the distribution of these personnel among fields of science and engineering was obtained from the 1974 survey, and is shown below.

Distribution of the 1970 science and engineering labor force by field, 1974

Field	Percent
Engineers	64
Physical scientists	14
Life scientists	7
Computer scientists	5
Social scientists	4
Psychologists	3
Mathematical scientists	3

The following are some additional characteristics of the 1970 science and engineering labor force, surveyed in 1974:[3]

- Approximately 35 percent of the employed scientists and engineers are engaged in work supported with Federal funds.
- Industry and business are the employers of most scientists and engineers, 65 percent of the total in 1974.
- Scientists and engineers holding doctoral degrees account for some 15 percent of the scientific and engineering population, master's and professional degree holders almost 25 percent, and baccalaureates nearly 60 percent.
- Management or administration was the most common work activity in which scientists and engineers were engaged in 1974; this activity was reported by about 30 percent of the sample, with about one-third (10 percent of the total employed group) involved in the management or administration of R&D.
- Research and development was the primary work activity of almost 30 percent of the employed scientific and engineering population, with almost 10 percent involved in research (applied and basic).

Doctoral scientists and engineers

Those scientists and engineers holding doctoral degrees represent, as a group, the most highly trained men and women in their professions. The investment of resources in their education and training is significant in both monetary terms and in the amount of time involved. The characteristics and activities of this group warrant careful monitoring, since doctoral level scientists and engineers provide leadership for the entire scientific community.

It is estimated that in 1973 there were 245,000 doctoral scientists and engineers in the United States.[4] This number is over twice that reported in 1963, and represents about 14 percent of all scientists and engineers. Approximately 9 percent of the 245,000 doctoral scientists and engineers were women and 6 percent were foreign citizens. Scientists and engineers of oriental background made up 5 percent of the doctorate science and engineering population; Blacks, 1 percent; and other groups, 94 percent.[5]

The physical and life sciences were the two largest fields represented in the 1973 population of doctoral scientists and engineers, as shown below.[6]

Distribution of doctoral scientists and engineers, by field, 1973

Field	Percent
Life scientists	26
Physical scientists	26
Engineers	15
Social scientists	13
Psychologists	12
Mathematical scientists	6
Computer scientists	1

Among doctoral scientists, the proportion accounted for by physical scientists declined over the 1966-73 period while the life scientists' share increased. Other fields remained relatively constant over the period in terms of their relative proportions (figure 5-1).

Sectors of doctoral employment. The pattern of employment of doctoral scientists and engineers in 1973 is shown in figure 5-2. Doctoral scientists are predominantly employed by educational institutions (64 percent); within

[3] "National Sample of Scientists and Engineers: Changes in Employment 1970-72 and 1972-74", *Science Resources Studies Highlights,* National Science Foundation (NSF 75-309), May 19, 1975.

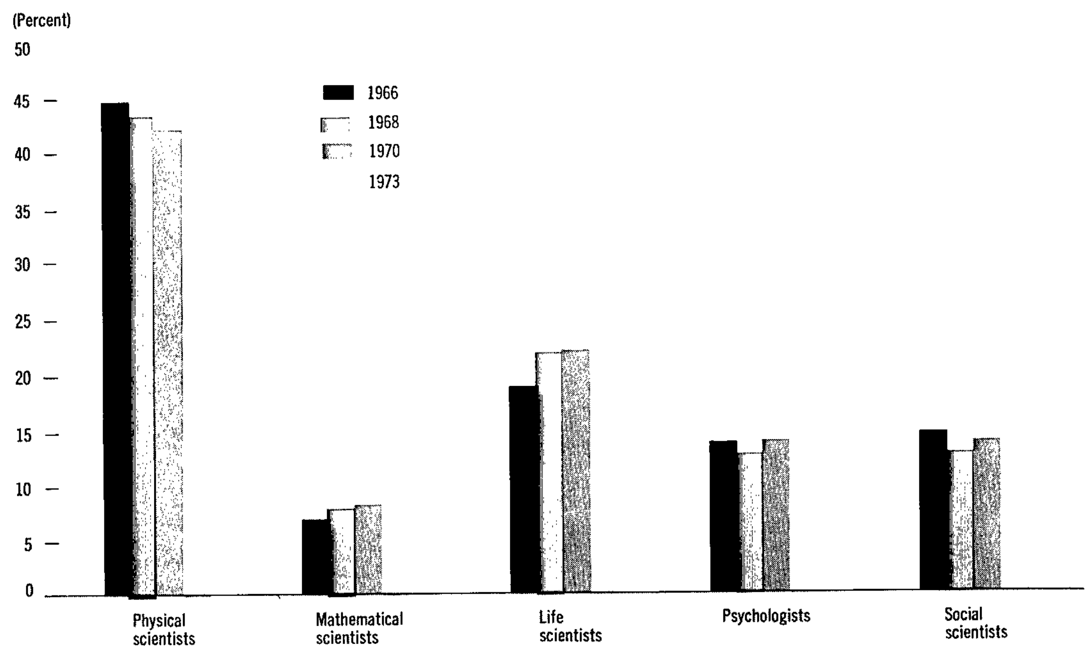
[4] *Doctoral Scientists and Engineers in the United States, 1973 Profile,* National Academy of Sciences, 1974.

[5] For further information on this topic, see the subsequent section in this chapter entitled "Women and Minorities in Science and Engineering."

[6] *Characteristics of Doctoral Scientists and Engineers in the United States, 1973,* National Science Foundation (NSF 75-312).

Figure 5-1

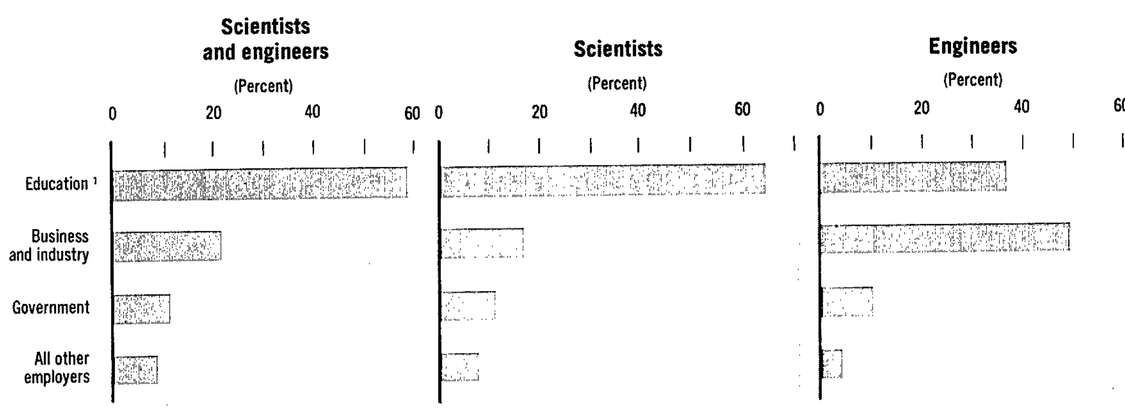
Estimated percent distribution of doctoral scientists, by field, 1966-73



SOURCE: National Science Foundation.

Figure 5-2

Percent distribution of employed doctoral scientists and engineers, by employment sector, 1973



[1] Universities and colleges account for 99 percent of the doctoral scientists and engineers in education.
SOURCE: National Science Foundation.

this group 61 percent are employed by four-year colleges and universities and 2 percent by two-year colleges. During the period 1966-70, there was a shift in the proportion of doctoral scientists employed by business and educational institutions, the former declining and the latter increasing. However, in view of enrollment trends and financial problems of institutions of higher education, this shift is not expected to continue.

Doctoral engineers as a separate group exhibit a different pattern of employment from scientists, with nearly half of them employed in the industrial sector.

Primary work activities of doctoral scientists and engineers. The activities in which doctoral scientists and engineers were primarily involved are indicated in figure 5-3. The data do not show the time allocated among the several activities of doctoral scientists and engineers, but rather the activity reported as occupying the largest portion of their time. Teaching and R&D represent the primary work activities of doctoral scientists, the majority of whom are employed in universities and colleges. A declining proportion of the doctoral scientists, however, were involved in R&D as a primary work activity during the period 1966-73. This decline of about 10 percent was accompanied by a relatively larger increase in the fraction reported as primarily teaching[7] (figure 5-4).

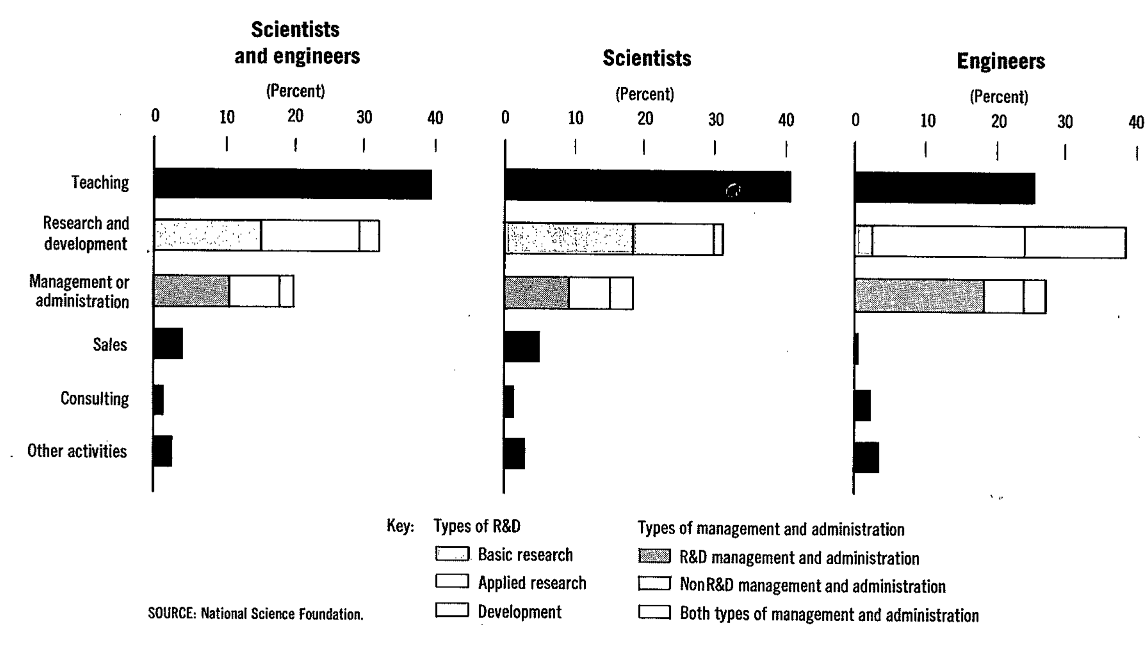
Of the 32 percent of the doctoral scientists primarily engaged in R&D, over one-half were working in basic research, over one-third were involved in applied research, and only a small percentage in development and design. The number of such scientists primarily engaged in management activities, however, was nearly the same as the total number primarily involved in basic research (30,851 versus 31,213).

The preceding discussion concerning the utilization of doctoral scientists and engineers provides, for the most part, a description of the characteristics of these doctorate holders in 1973. Over time, however, there has been movement from initial doctoral disciplines into other fields of science, while others have shifted

[7] This topic is discussed in more detail later in this chapter.

Figure 5-3

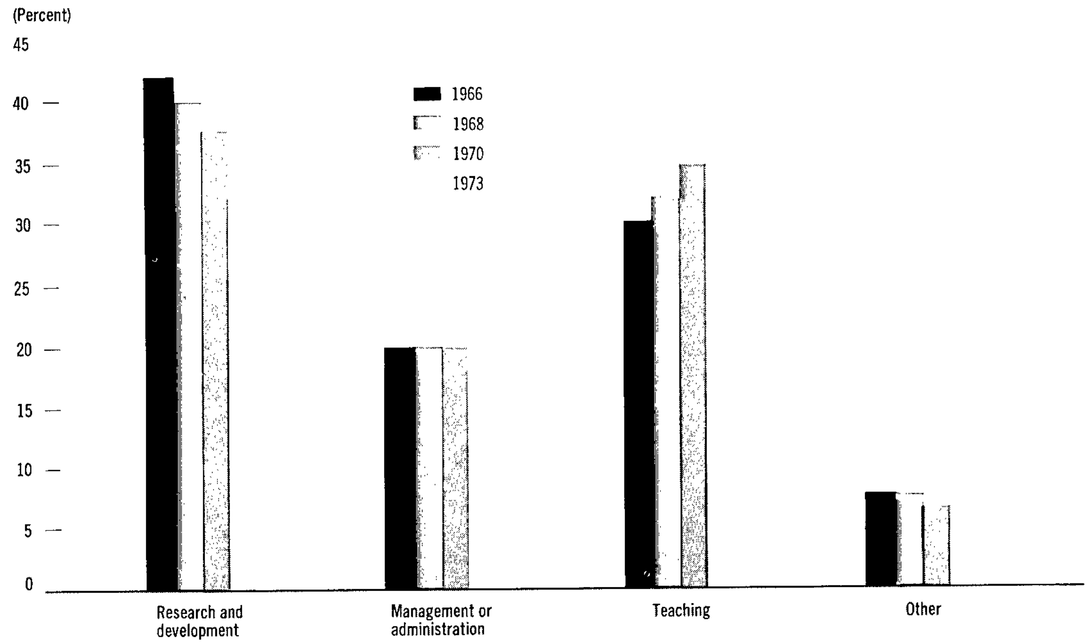
Percent distribution of employed doctoral scientists and engineers, by primary work activity, 1973



SOURCE: National Science Foundation.

Figure 5-4

Estimated percent distribution of doctoral scientists, by primary work activity, 1966-73



SOURCE: National Science Foundation.

to nonscience occupations. Between 10-30 percent of the doctorates in each field are employed in fields different from their doctorate field. The fields of bioscience, mathematics, and psychology experience the highest retention rates, with approximately 90 percent of the doctorates in these fields still employed in the same field of their doctorate, while physics and chemistry have the lowest retention rates (approximately 70 percent). Data on shifts to nonscience occupations show 11 percent of the doctoral social scientists changing fields, compared to 6 percent of the doctoral chemists and doctoral psychologists.[8]

Academic employment of scientists and engineers

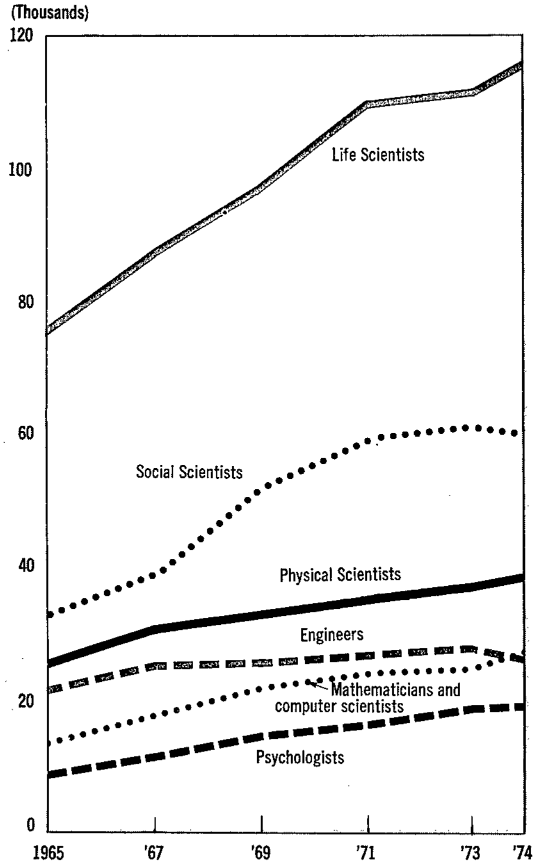
Universities and colleges employed about 288,100 scientists and engineers in 1974 (including full-time and part-time personnel), an increase of 61 percent over the 178,900 employed in 1965. Most of the growth occurred between 1965 and 1971, with increases in all scientific disciplines. The average annual rate of growth in academic employment of scientists and engineers between 1971-74 was only 1.7 percent compared with 7.3 percent during 1965-71. In absolute terms, the largest growth occurred in the employment of life scientists and social scientists, which together accounted for more than three-fifths of the overall increase between 1965-74 (figure 5-5). In two fields, engineering and social sciences, there were small declines in employment from 1973 to 1974.

As demand slackened for academic employment during the early 1970's, the attainment of the doctoral degree in the sciences and engineering became increasingly important as a requisite for employment in this sector. Since 1971, academic scientists and engineers with Ph.D.'s or health profession doctorates increased about 10 percent, compared with small declines in the employment of persons with master's or bachelor's degrees (figure 5-6). Between 1965 and 1974, employment of doctorates in universities and colleges increased by more than 60

[8] *Doctoral Scientists and Engineers in the United States, 1973 Profile*, National Academy of Sciences, 1974.

Figure 5-5

Scientists and engineers employed in universities and colleges, by field of employment, 1965-74



SOURCE: National Science Foundation.

percent, with the result that by 1974, 65 percent of all academic scientists and engineers had doctorate degrees, compared with 60 percent in 1965.

Primary work activities among academic scientists and engineers have shifted toward more teaching and less R&D (figure 5-7). In 1974, 17 percent of all science and engineering professionals working in institutions of higher education were primarily engaged in R&D, compared with 22 percent in 1965. A part of this shift is due to the rapid growth of two-year academic institutions where teaching is the primary activity of almost all the faculty. Other academic institutions, including the large research universities, also experienced the shift toward more teaching. During 1969-74, four-year institutions reported an average annual percentage rise of 4.7 percent in the number of scientists and engineers working primarily as teachers, compared with only a 0.4 percent average annual growth of those working primarily in R&D.[9]

This shift in utilization occurred at the same time as the reduction in the rate of growth in Federal support for academic R&D. From 1968 to 1974, annual increases in Federal R&D support to universities and colleges have not kept pace with increases in inflation; such support in constant dollars has declined about 8 percent in this six-year period. The financial status of R&D in this sector might have been worse except for substantial increases in separately budgeted R&D support by the institutions themselves, and by State and local governments. Funds from the latter increased some 6 percent annually in constant dollars between 1968 and 1974 for a total growth of nearly $70 million. Support from the institutions' own funds rose at an average annual rate of 2.5 percent over the period for a total of almost $35 million. Federal support over the same period, on the other hand, declined by more than $60 million in constant dollars.[10]

Selected characteristics of higher education faculty. Significant changes have occurred in recent years in the characteristics of the faculty of academic institutions, in terms of their median age, tenure status, and number of years since receipt of doctorate.

Between 1968 and 1974, the overall proportion of young[11] doctoral faculty in doctorate-level science and engineering departments decreased substantially, dropping from 42 percent to 28 percent of the total doctoral faculty.[12] For the fields shown in the table below, the total number of full-time faculty increased

[9] *Manpower Resources for Scientific Activities at Universities and Colleges, January 1974*, Detailed Statistical Tables, National Science Foundation (NSF 75-300-A), and earlier volumes.

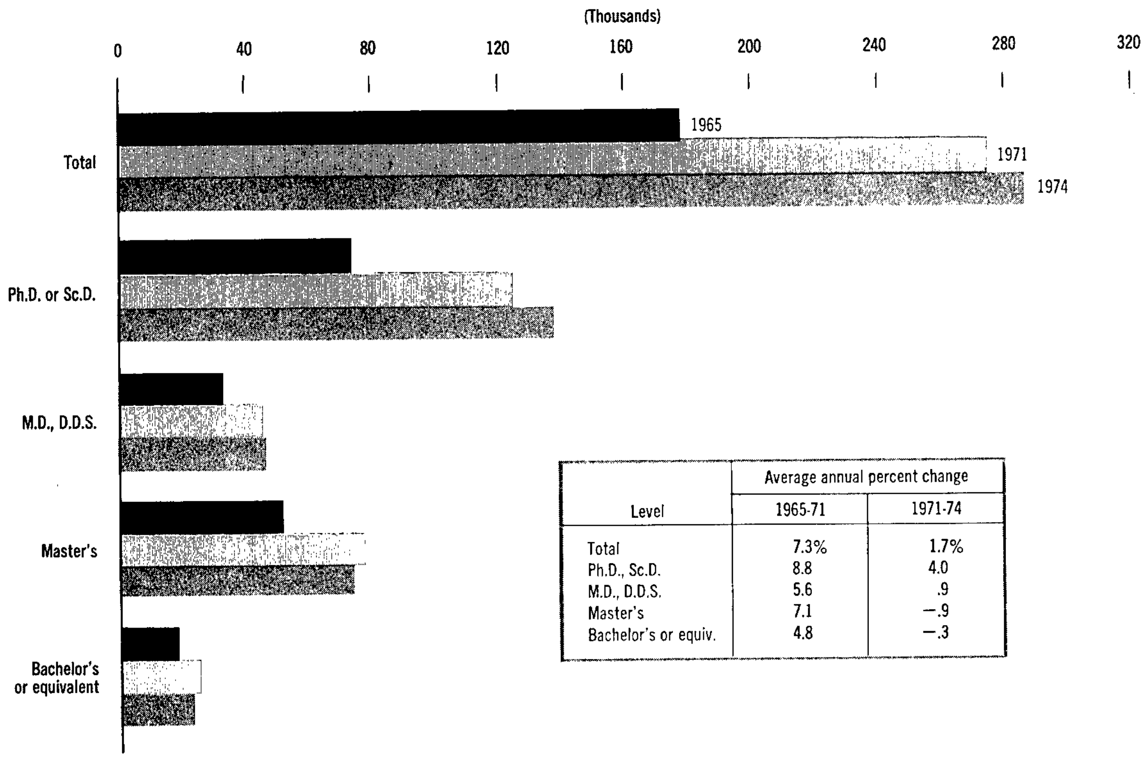
[10] "Separately Budgeted Academic R&D Expenditures Decline in Real Terms in FY 1974", *Science Resources Studies Highlights*, National Science Foundation (NSF 75-306), April 21, 1975.

[11] Those who had held doctorates for seven years or less at the time of each study.

[12] *Young and Senior Science and Engineering Faculty, 1974: Support, Research Participation, and Tenure*, National Science Foundation (NSF 75-302).

Figure 5-6

Employment of academic scientists and engineers, by level of attainment, 1965-74



Level	Average annual percent change 1965-71	1971-74
Total	7.3%	1.7%
Ph.D., Sc.D.	8.8	4.0
M.D., D.D.S.	5.6	.9
Master's	7.1	−.9
Bachelor's or equiv.	4.8	−.3

SOURCE: National Science Foundation.

by 8 percent from 1968 to 1974. However, the young doctorate faculty proportions declined in all seven fields, while even the absolute numbers of young doctorate faculty decreased in 5 of the fields, biology and psychology being the only exceptions.

Proportion of young[13] doctoral faculty in doctoral level science and engineering departments in universities and colleges, by selected fields, 1968 and 1974

Selected fields	Young doctoral faculty as a percent of all doctoral faculty 1968	1974
Biology	32	27
Chemistry	35	21
Economics	43	34
Electrical engineering	52	27
Mathematics	52	36
Physics	40	19
Psychology	43	37

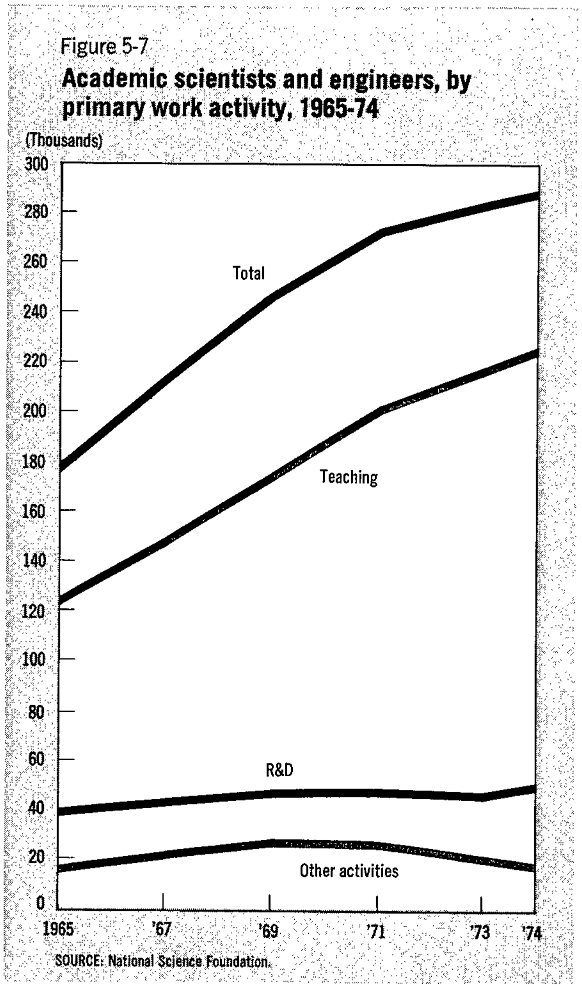
[13] Those who had held doctorates for seven years or less at the time of each study.

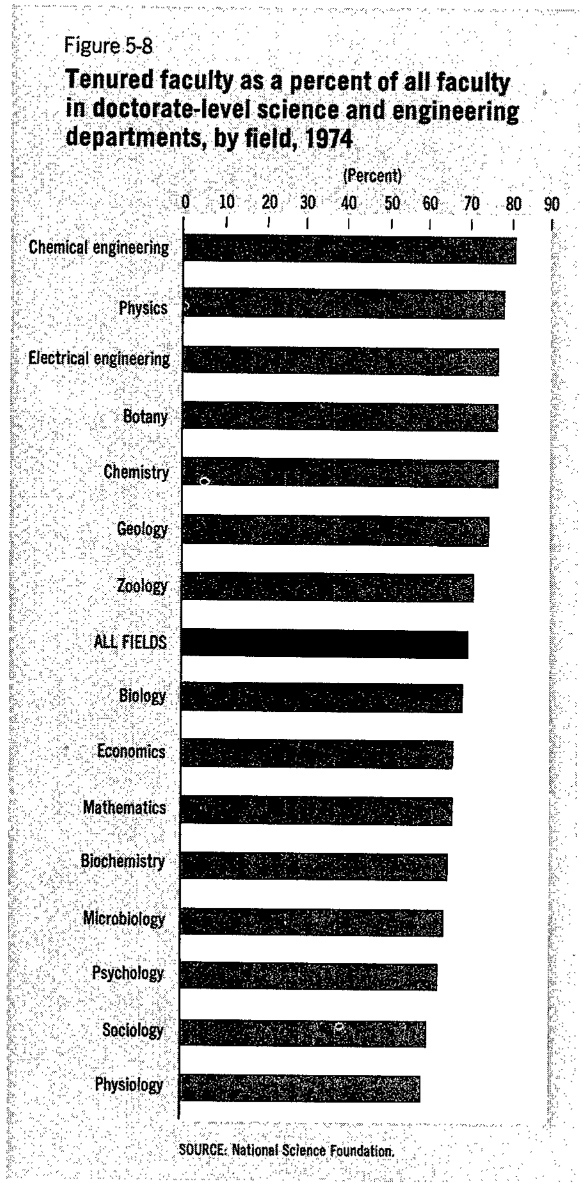
Another recent trend is the substantial increase in the proportion of faculty with tenure. An American Council on Education study[14] found in 1973 that 65 percent of the faculty in all fields were tenured, compared with 47 percent in 1969. Figure 5-8 presents more recent NSF data which show the 1974 proportions of tenured faculty in doctoral level science and engineering departments for 15 fields. Overall, 70 percent of these faculty have tenure, with the proportions ranging from a high of 81 percent in chemical engineering to 59 percent in physiology.

Between 1969 and 1973, the median age of faculty in science and engineering fields employed in doctorate-granting institutions rose from 41 to 44 years.[15] Changes in the

[14] Alan E. Bayer, *Teaching Faculty in Academe: 1972-73*, (Washington, D.C.: American Council on Education, 1973).

[15] Bayer, *Ibid.*, and Alan E. Bayer, *College and University Faculty: A Statistical Description*, (Washington, D.C.: American Council on Education, 1970).





median age of faculty for several science and engineering fields are presented in the table below.

Median ages of science and engineering faculty in doctorate-granting universities and colleges, 1969 and 1973[16]

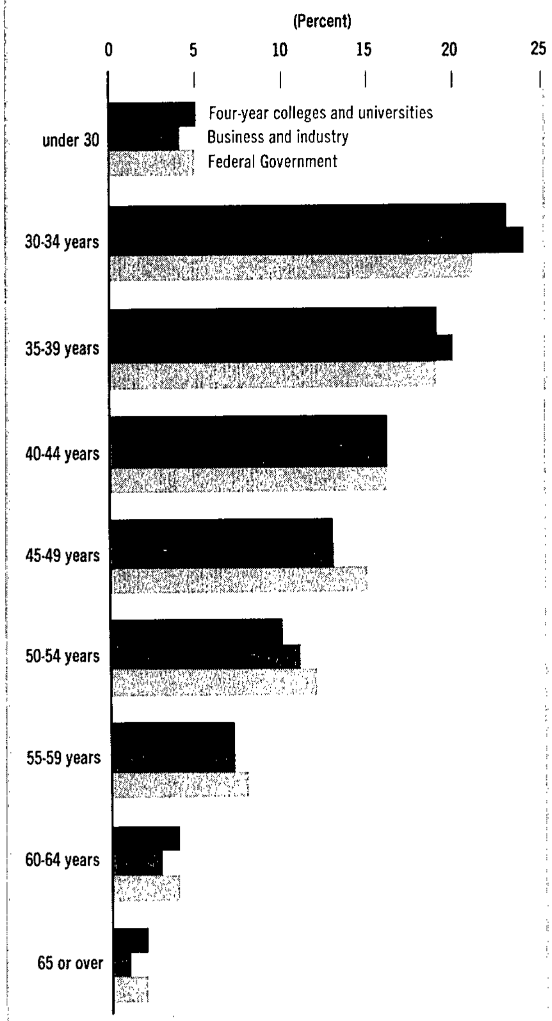
Field	1969	1973
All science and engineering fields ...	41	44
Biological sciences	43	46
Chemistry	39	43
Earth sciences	40	43
Engineering	41	47
Mathematics	37	39
Physics	39	43
Psychology	39	43
Social sciences	39	43

[16] National Science Foundation and American Council on Education, special tabulations.

It should be noted that age distributions among academic science and engineering doctorate faculties do not differ greatly from those for doctoral scientists and engineers in other employment sectors (figure 5-9). While the older age pattern displayed by science and engineering faculty is related to the decreasing number of new faculty appointments, the relatively small proportion of employed doctorates under the age of 30 may be accounted for in part by the time required to attain a doctorate. In recent years, the median time-lapse between the

Figure 5-9

Age distribution of doctoral scientists and engineers, by type of employer, 1973



SOURCE: National Science Foundation.

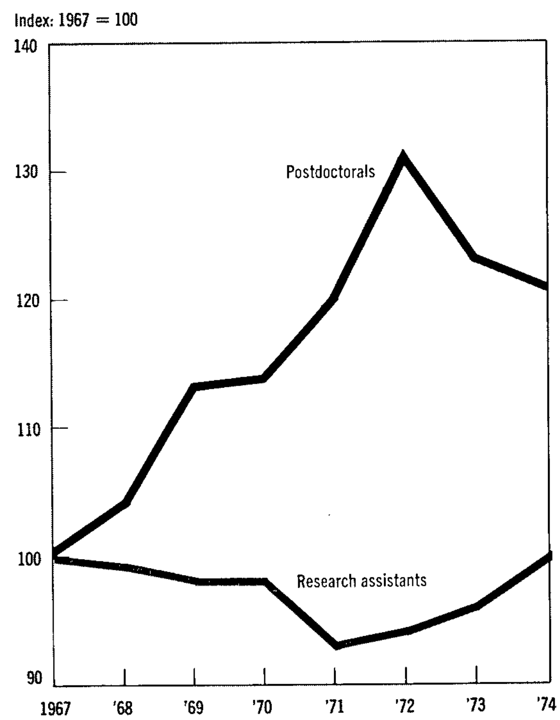
baccalaureate and the doctorate has been approximately 7 to 8 years.[17]

Inherent in the age and tenure data is an implication that the pattern in many fields over the next 5 to 10 years may be that of a relatively senior faculty, the great majority of whom will be tenured. However, it is possible that for some fields these recent trends could be reversed if in the future, replacement openings for science and engineering faculty caused by death and retirement are filled extensively with new junior faculty on academic staffs.

Utilization of postdoctoral personnel. Between 1967 and 1974, the number of science and engineering postdoctorals, as indicated by a survey of representative science and engineering departments in doctorate-granting institutions, increased by 21 percent, reaching almost 17,000 in 1974 (figure 5-10).[18] The reasons for these increases may have changed midway during this period. In the late 1960's, universities provided increasing numbers of

Figure 5-10

Postdoctorals and research assistants in science and engineering departments at doctorate-granting institutions, 1967-74



SOURCE: National Science Foundation.

[17] *Doctorate Recipients from U.S. Universities: Summary Report*, National Academy of Sciences, annual series.

[18] The indices for 1967-71 are estimates based on applications submitted to NSF for its departmental traineeship program. Indices after 1971 were collected by the "Survey of Graduate Science Student Support and Postdoctorals" for matched departments.

postdoctoral appointments as part of the general academic science expansion. Between the late 1960's and the early 1970's, however, academic science funding from the Federal Government leveled off (in constant dollar terms), while the employment market for new doctorates, especially in academic institutions, declined markedly.

Although fewer academic R&D funds were available, there are at least two possible reasons for increases in the postdoctoral population between 1967 and 1974. Both new doctorates and the universities at which they worked may have used the postdoctoral appointments as a "holding pattern" until new Ph.D.'s could find desirable positions. This reason was given by over 35 percent of science and engineering postdoctorals in a recent study.[19] A second possible reason is the interest of academic researchers in maximizing their research effectiveness in periods of financial stress. One way to accomplish this may have been to substitute postdoctorals for research assistants during the earlier years of the 1967-74 period, a pattern which is suggested by the data in figure 5-10.

A high in the number of academic postdoctoral appointments was reached in 1972 followed by a decline resulting primarily from decreases in the number of postdoctoral appointments of "recent" doctorates (i.e., those who had earned their doctorates within four years of the study). In 1972 these recent degree recipients comprised 72 percent of all postdoctorals, compared with 58 percent in 1974.

Industrial employment of scientists and engineers

The industrial sector is by far the largest employer of scientists and engineers.[20] There was, however, some fluctuation in the level of employment during the 1970-74 period, reflecting first the layoffs of scientific and technical personnel in industry in 1971-72, and then the general upturn in the economy during late 1973 and early 1974. Scientists and engineers employed in industry in 1970 constituted almost two-thirds of all such personnel employed in that year, but increased in the two subsequent years so that the level in early 1974 was near that of 1970.

Engineers accounted for nearly 80 percent of the scientists and engineers employed in the industrial sector in 1974. Physical scientists (including those in the environmental sciences) accounted for 11 percent of the total and computer scientists, 6 percent.

In 1974, R&D and its management constituted the largest primary activity of industrial scientists and engineers, involving almost 30 percent of the total group. However, as shown in the table below, there were some differences between the activity patterns of scientists and engineers. A larger fraction of industrial scientists were primarily engaged in R&D and management of R&D (36 percent) than was the case for engineers (26 percent). The next most common activity of industrial engineers was management of non-R&D activities, while for scientists it was the area of computer applications.

Percent distribution of the 1970 science and engineering labor force employed in industry, by primary work activity, 1974[a]

Primary work activity	Total	Scientists	Engineers
R&D and R&D management	29	36	26
Management of non-R&D activities	19	15	20
Production and inspection	16	13	17
Design	14	NA	18
Computer applications	6	19	2
Other activities	16	17	17

[a] NSF, special tabulations

The Federal Government provided support for 23 percent of all industrial scientists and engineers in 1974 versus 28 percent in 1972. This decrease was evident among most fields. In both years, much of the Federal support was for industrial R&D activities. The estimated relative level of support varied widely among the different science fields. In 1974, 26 percent of the engineers and 22 percent of the mathematical scientists received Federal support; the same was true for only 10 percent of the physical scientists and approximately 5 percent of the life and environmental scientists.

Over half—52 percent—of all Federal support of scientists and engineers in 1974 came from

[19] *Characteristics of Doctoral Scientists and Engineers in the United States, 1973,* National Science Foundation (NSF 75-312-A).

[20] "National Sample of Scientists and Engineers: Changes in Employment, 1970-72 and 1972-74", *Science Resources Studies Highlights,* National Science Foundation (NSF 75-309), May 19, 1975.

the Department of Defense, with another 17 percent provided by the National Aeronautics and Space Administration. With the exception of life and environmental scientists, engineers and scientists in industry received their major Federal support from the Department of Defense.

Employment of scientists and engineers in the Federal Government

Nearly 10 percent of all scientists and engineers are employed by U.S. Government agencies. The number of Federal scientists and engineers in 1973 declined by 3 percent over 1972 to 162,000, the first sizable annual reduction since data were initially collected in 1954.[21]

The major agencies employing scientists and engineers are shown below in terms of the percentage of the total employed by each during 1973.

Distribution of Federal scientists and engineers, by agency, 1973

Agency	Percent
DOD	45
USDA	15
Interior	8
NASA	7
Commerce	4
HEW	4
All other agencies	16

Of all Federal scientists and engineers, some 30 percent were employed in R&D positions in 1973. Those engaged in research consisted of nearly 19,000 scientists and some 4,000 engineers, whereas development activities employed nearly 19,000 engineers and over 6,000 scientists.

Employment of scientists and engineers in nonprofit institutions

These institutions[22] employ only about 1 to 2 percent of the national total of scientists and engineers. By 1973, employment of scientists and engineers in this sector reached approximately 26,300, an increase of some 20 percent since 1965.[23] In contrast to trends reported in the academic sector, virtually all of the increase in independent nonprofit institutions was attributable to personnel who worked primarily in research and development; this group of personnel comprised nearly 90 percent of all scientists and engineers employed in such institutions.

RESEARCH AND DEVELOPMENT PERSONNEL

Total scientists and engineers in R&D

An estimated 530,000 scientists and engineers were engaged in R&D activities on a full-time equivalent basis in all sectors of the economy in 1974. This number accounts for approximately one-third of all employed scientists and engineers.[24]

Over the past two decades, the employment of these R&D scientists and engineers grew at an average annual rate of 4.1 percent, 1.6 times faster than the rate of growth of total civilian employment. In 1969-70, however, the long-term growth trend was reversed as the number of R&D scientists and engineers declined and national R&D expenditures in constant dollars decreased. Between 1973 and 1974, R&D scientist and engineer employment increased by nearly 5,000, reversing the downward trend slightly. The 1974 employment level, however, was over 30,000 short of the peak employment level reached in 1969.

Doctoral scientists and engineers in R&D

Approximately 90,000 of the science and engineering doctorates in the 1973 U.S. labor force cited R&D or R&D management as their primary work activity.[25] While some one-third of all scientists and engineers were engaged in R&D, the proportion of doctorates primarily

[21] "Federal Scientific and Technical Personnel Decline in 1973", *Science Resources Studies Highlights*, National Science Foundation (NSF 74-316), October 18, 1974.

[22] Which include research institutes, hospitals, and Federally Funded Research and Development Centers administered by nonprofit institutions.

[23] *R&D Activities of Independent Nonprofit Institutions, 1973*, National Science Foundation (NSF 75-308).

[24] See Appendix table 2-2 and *National Patterns of R&D Resources, 1953-75*, National Science Foundation (NSF 75-307).

[25] *Characteristics of Doctoral Scientists and Engineers in the United States, 1973*, National Science Foundation (NSF 75-312).

involved in R&D-related work exceeded 40 percent.

The 1973 distribution of these scientists and engineers by field of science and work activity is shown in figure 5-11. Engineers represent the major portion of those with development as a primary work activity, while physical and life science doctorates constitute the major portion of those involved in research. A relatively large proportion of R&D doctorates spend the major part of their time in R&D administration.

The 1973 distribution of R&D doctorates by type of employer is shown in figure 5-12. In contrast to the pattern for all R&D scientists and engineers, the doctorates are about equally concentrated in industry and educational institutions, for all fields combined. Information on the distribution by type of employer for major fields of science is presented in figure 5-13. Physical science and engineering R&D doctorates are most heavily concentrated in industry, while life scientists, mathematical scientists, and social scientists are located predominantly in educational institutions.

The concentration of R&D doctorates by employment sector varies considerably. Almost three-quarters of the doctorates employed in industry are engaged primarily in R&D or R&D management, while the R&D involvement of doctorates employed in government is slightly higher. In academic institutions, where teaching is the chief activity, only one-fourth of the doctorates work primarily in R&D.

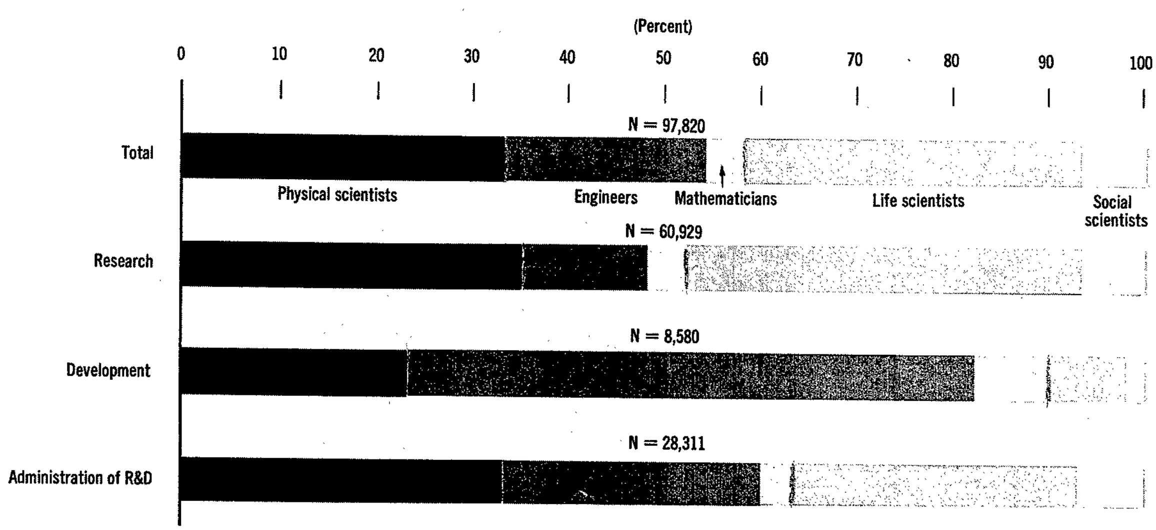
R&D in the academic sector

Some 67,000 or 13 percent of the Nation's full-time equivalent R&D scientists and engineers were employed in universities and colleges in 1974;[26] approximately 26 percent (18,000) of these are graduate students working as scientists and engineers. In contrast to other sectors of employment, university and college personnel involved in R&D are usually primarily engaged in teaching. Thus, the actual number of faculty members engaged in R&D may be considerably greater than the reported FTE number of 67,000. A 1973 survey of U.S. science and engineering doctorates showed that about 80,000 of the science and engineering doctorates employed by universities and colleges considered

[26] *National Patterns of R&D Resources, 1953-75*, National Science Foundation (NSF 75-307).

Figure 5-11

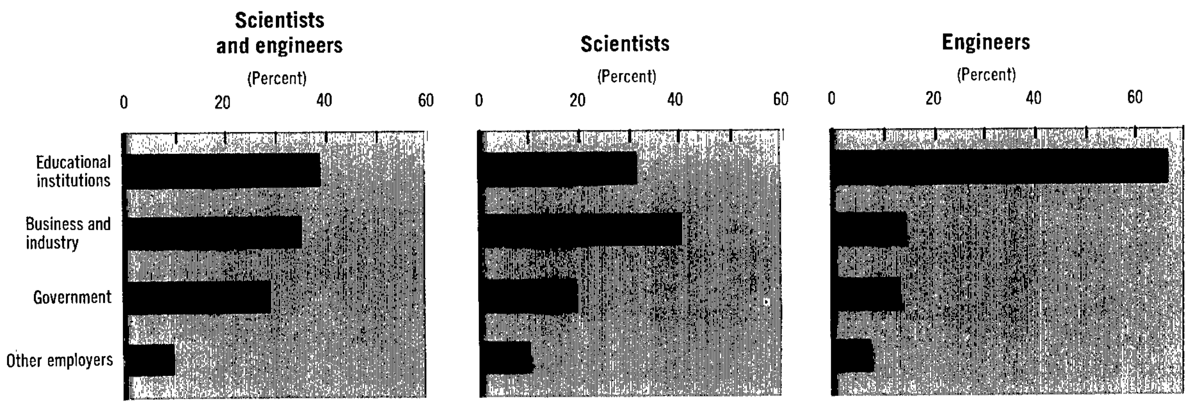
Distribution of doctoral scientists and engineers within R&D activities, by field, 1973



SOURCE: National Science Foundation.

Figure 5-12

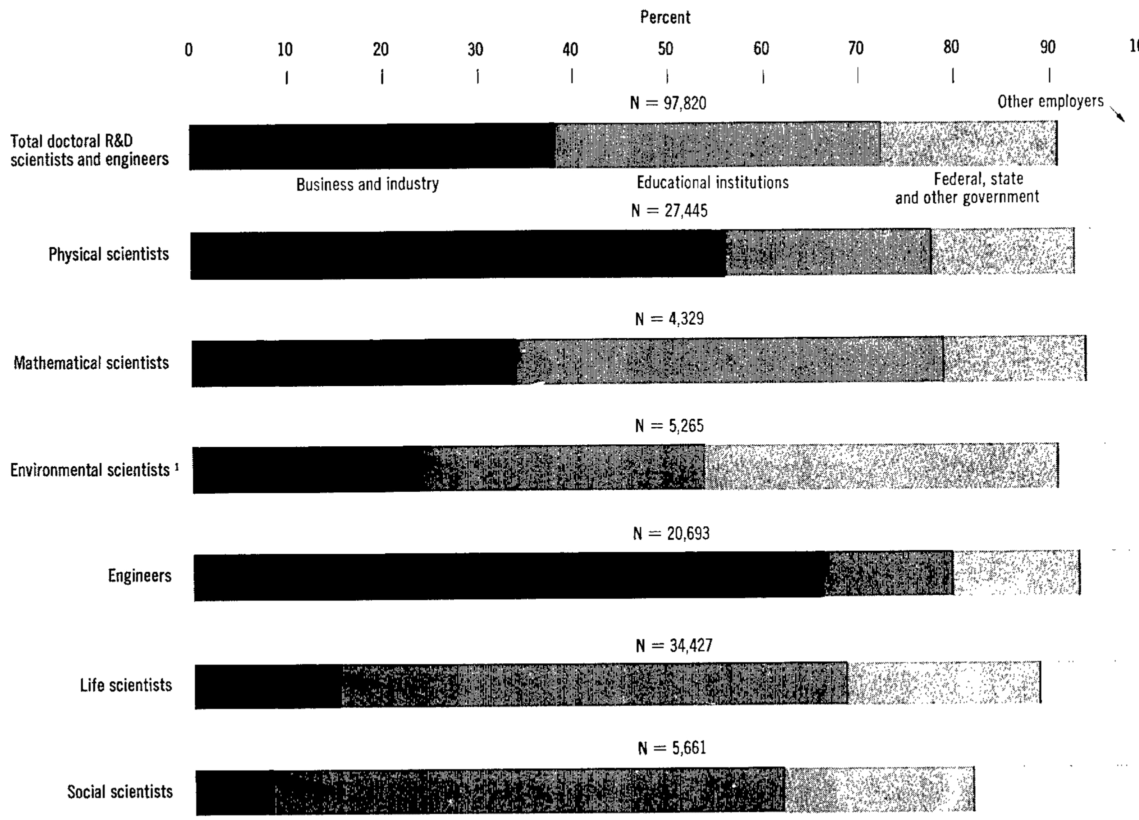
Doctoral R&D scientists and engineers, by type of employer, 1973



SOURCE: National Science Foundation.

Figure 5-13

Distribution of doctoral R&D scientists and engineers, by field and type of employer, 1973



¹ Includes earth scientists, oceanographers, and atmospheric scientists.
SOURCE: National Science Foundation.

themselves involved in R&D as a primary or a secondary activity.[27]

The type of R&D carried out by these academic scientists and engineers is heavily focused in the research area. An indicator of the extent of this concentration is R&D expenditures; in 1974, 96 percent of academic R&D funding was expended for research activities (basic and applied), with only 4 percent reported for development activities.[26]

The extent of the involvement in research by scientists and engineers who have recently received doctoral degrees is indicated in figure 5-14. This figure applies to those faculty spending 20 percent or more of their time in R&D; young investigators are defined as those who had held their doctorate seven years or less at the time of each of the studies. The proportion of young investigators in relationship to the total number of faculty investigators has decreased significantly. These decreases, however, match the overall changes in faculty age distribution, regardless of activity. The physical sciences and electrical engineering have been most affected, while the decreases in young investigators have been least pronounced in biology and psychology.

In 1974, more than one-half of the faculty investigators[28] in the fifteen fields listed in the table below were performing R&D directly connected with project grants and contracts awarded by Federal agencies.[29] This represents a considerable decrease from 1968, when two-thirds of faculty investigators were involved in Federal projects. There were large differences among the several scientific fields, however. For

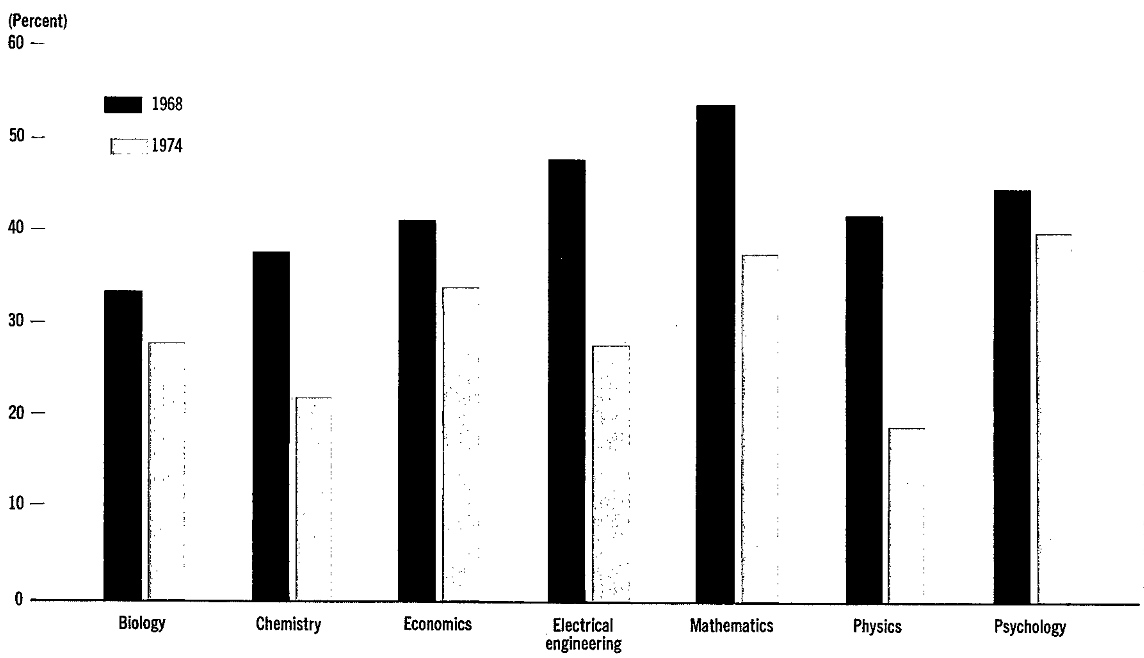
[27] National Science Foundation, special tabulations.

[28] "Investigators" were defined as those spending at least 20 percent of their time in research.

[29] *Young and Senior Science and Engineering Faculty, 1974: Support, Participation, and Tenure,* National Science Foundation (NSF 75-302).

Figure 5-14

Young doctorate faculty[1] investigators[2] as a percent of all faculty investigators, 1968 and 1974



[1] Those who had held doctorates seven years or less at the time of each study.
[2] Spending 20 percent or more of their time in research.
SOURCE: National Science Foundation.

example, more than three-fourths of the faculty investigators in biochemistry, but only one-fourth of those in sociology, were doing research connected with federally supported projects in 1974.

Proportion of faculty investigators performing R&D connected with Federal grants and contracts, by field, 1974

Field	Percent whose research was federally supported
All fields	56
Biochemistry	78
Physiology	75
Microbiology	74
Physics	72
Electrical engineering	71
Chemical engineering	65
Biology	62
Geology	59
Chemistry	58
Zoology	52
Psychology	43
Mathematics	42
Botany	42
Economics	30
Sociology	26

R&D in industry

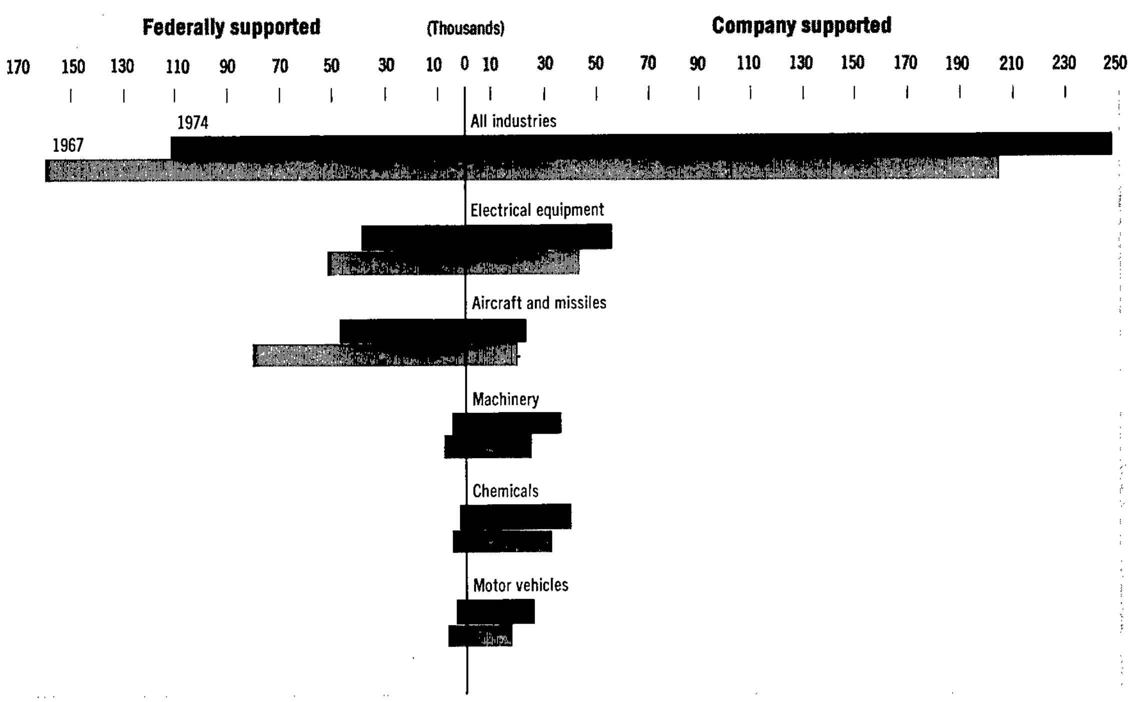
The number of R&D scientists and engineers (on a full-time equivalent basis) in industry was at its highest level in 1969, declined in later years through 1972, and then increased in 1973 and 1974, bringing the number to approximately its 1971 level (360,000, or 68 percent of all R&D scientists and engineers).[30] The recent increases occurred primarily in the chemical, machinery, and electrical equipment industries; the largest decline since 1969 occurred in the aircraft and missiles industry.[31] These four industries are among the leading industrial employers of R&D scientists and engineers, accounting for almost 70 percent of the industrial total in 1974.

The Federal Government is a major source of support for industrial R&D activities; 32 percent of industrial R&D scientists and engineers were supported by Federal funds in 1974 (figure 5-15).

[30] These and other aspects of industrial R&D are covered more fully in another chapter in this report entitled, "Industrial R&D and Innovation".
[31] See Appendix table 4-9b.

Figure 5-15

R&D scientists and engineers[1] employed in industry, by source of R&D funds, January 1967 and 1974



[1] Full-time equivalent basis.
SOURCE: National Science Foundation.

However, this represents a significant decrease from 1967 when the Federal share amounted to 44 percent. The relative decrease in federally supported R&D scientists and engineers is most evident in the machinery, aircraft, and motor vehicle industries. As shown in the figure, almost 80 percent of the federally supported R&D scientists and engineers are employed in the electrical equipment and aircraft and missiles industries, both of which are heavily involved in space and defense R&D.

UNEMPLOYMENT AMONG SCIENTISTS AND ENGINEERS

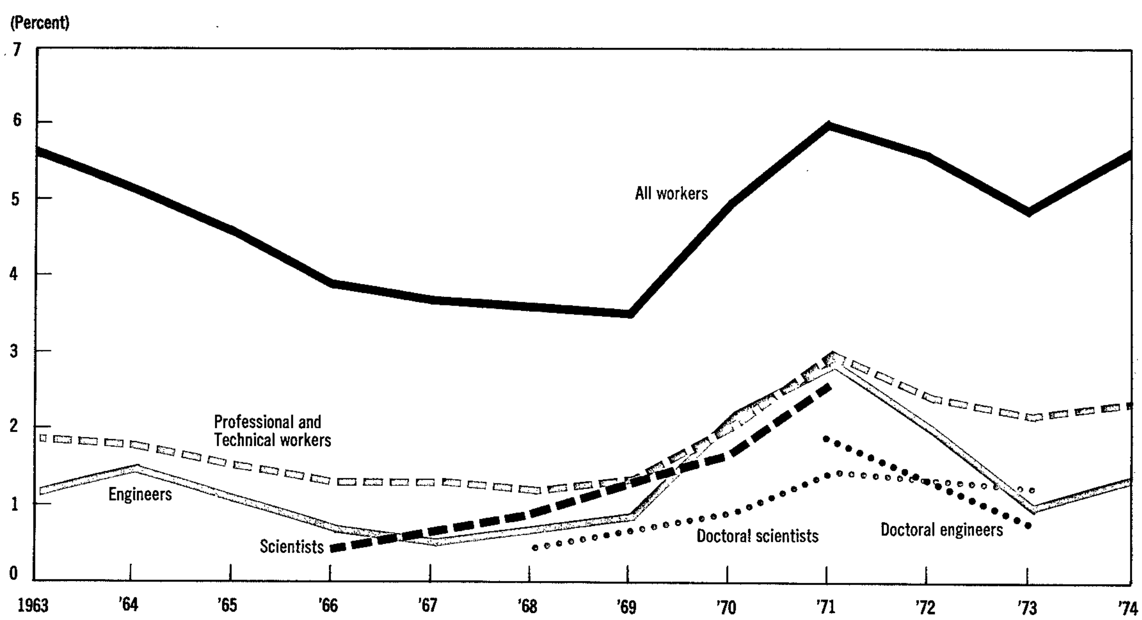
Employment of scientists and engineers during most of the 1960's rose substantially in all sectors. Unemployment was low, ranging around 1 percent, and for most of the period remained about three-fourths of the level for all professional, technical, and kindred workers, and no more than one-fourth the rate for all workers in the country (figure 5-16). However, starting in the early 1970's, changes in the labor market for both scientists and engineers were brought about by a series of factors—cut-backs in defense and other R&D programs, the general economic downturn, and the beginning of the decline in academic recruiting. Thus, unemployment rates for scientists and engineers reached a level of around 3 percent at the beginning of 1971. At that point, the rate was nearly as high as that for all professional workers but only one-half that for all workers. Early in 1972 the employment situation began to improve. The unemployment rate for engineers alone dropped from 3.2 percent in the first quarter of 1971 to under 1 percent at the end of 1973—a rate similar to that of the mid-1960's.

In mid-1974 the unemployment rate for a sample of scientists and engineers was 1.1 percent.[32] Of those employed, 97 percent held full-time positions while 3 percent were working

[32] "National Sample of Scientists and Engineers: Changes in Employment 1970-72 and 1972-74", *Science Resources Studies Highlights,* National Science Foundation (NSF 75-309), May 19, 1975.

Figure 5-16

Average unemployment rates, 1963-74[1]



[1] Not seasonally adjusted.
SOURCE: Bureau of Labor Statistics and National Science Foundation.

part-time. In late 1974, the unemployment level for engineers alone was still only 1.9 percent.

Unemployment rates express only a part of the overall situation. The national unemployment rate, for example, is expressed in terms of occupation last held. In some cases an individual scientist or engineer may have previously taken a nonscience or nonengineering job before becoming unemployed and would therefore not be reported as a scientist or engineer. Unemployment levels, furthermore, do not indicate the extent of employment (part-time employment may be involuntary) nor the degree of underutilization in positions requiring lesser skills than individuals possess. In addition, in most instances it has not been possible to measure the difficulty or the length of time required for obtaining employment for scientists and engineers who are first entering the job market or for those who are changing jobs.

SUPPLY OF SCIENTISTS AND ENGINEERS

Early student interest in science and engineering

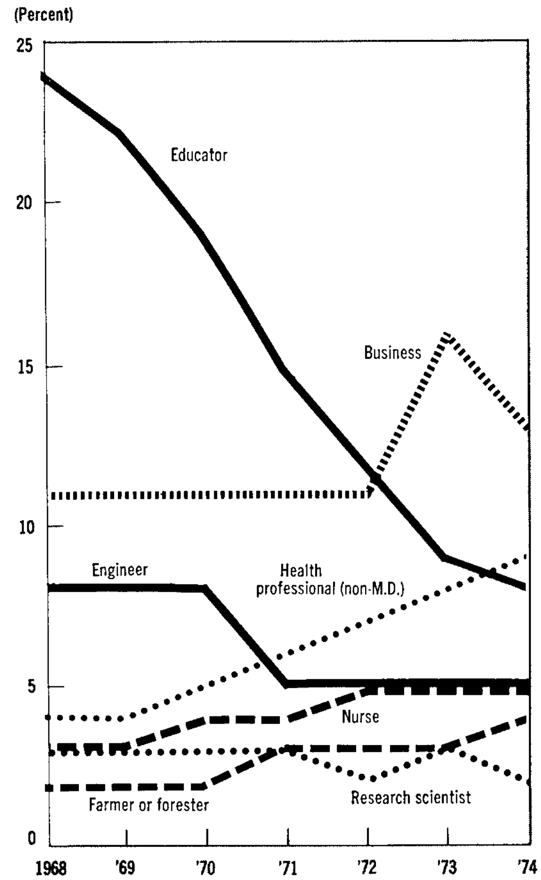
Information concerning occupational preferences of college freshmen provides an early indicator of student interest in science and engineering.[33] In recent years, interest has decreased in the occupations of research scientist, engineer, and educator, while increasing in those of medical doctor, nurse, and non-M.D. health professional (figure 5-17).

A second indicator of early interest in science and engineering is the choice of college majors by National Merit Scholars as they enter college (figure 5-18). The proportion of these students planning to enter science and engineering increased from 62 percent to 70 percent between 1966 and 1974. Between 1972 and 1974, however, there was a decline of two percentage points in the proportion of National Merit Scholars choosing science as a major, while over this same period, there was an increase of nearly three percentage points in those planning to major in engineering.

The earliest information about undergraduate enrollments by major field is obtainable in a

Figure 5-17

Occupational preference of college freshmen, 1968-74



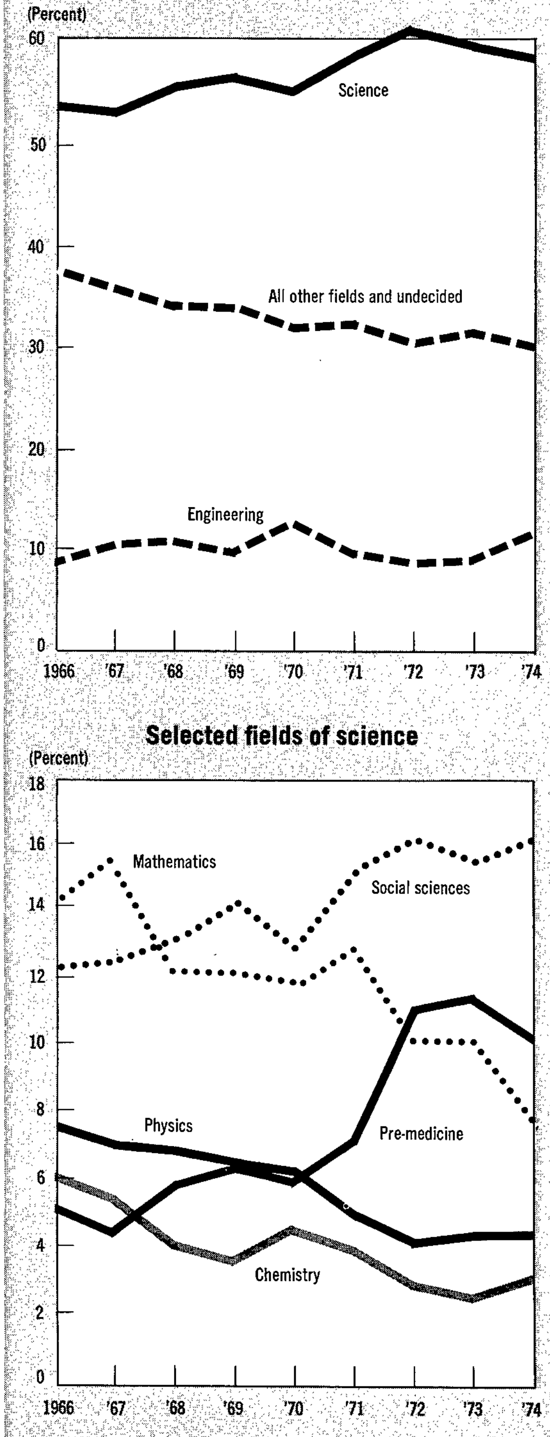
Source: American Council on Education and University of California, Los Angeles.

student's junior year. One study shows that total junior-year undergraduate enrollment increased by 3.2 percent in the fall of 1972 over the fall of 1971.[34] The number of students majoring in various science and engineering fields increased about 4.5 percent. Life science majors increased by more than 12 percent. Social science majors increased about 6 percent, and in the fall of 1972, they accounted for 47 percent of the science and engineering majors. Fewer students chose majors in engineering, mathematical sciences, and physics, while small increases occurred in chemistry and other physical science majors in the fall of 1972.

[33] *The American Freshman: National Norms*, American Council on Education and University of California, Los Angeles, annual series.

[34] J. E. Dutton and B. A. Blandford, *Enrollment of Junior-Year Students (1971 and 1972)*, (Washington, D.C.: American Council on Education, 1973).

Figure 5-18
College majors of National Merit Scholars, 1966-74



Source: National Merit Scholarship Corporation.

Bachelor's degrees awarded

Annual awards of bachelor's degrees in the sciences and engineering are shown in figure 5-19 for the years 1960 through 1972, the last year for which National Center for Educational Statistics data are available. Over the 1960-72 period, the annual recipients of science and engineering degrees doubled, including a tripling of the number of recipients of social science degrees. Social science degrees—as a proportion of all bachelor's degrees in science and engineering—rose from about 26 percent in 1960 to almost 50 percent in 1972.

Bachelor's degrees in science and engineering, as a fraction of bachelor's and first-professional degrees[35] in all fields, remained essentially constant at approximately 30 percent between 1960 and 1972. The large increases in annual recipients of social science degrees were responsible for maintaining the fraction at a constant level; engineering degrees, as a proportion of degrees in all fields, declined continuously from 10 percent to 5 percent during the period and the physical sciences fell from 4 percent to 2 percent.

Graduate enrollments in science and engineering

Enrollments in the various fields at the graduate level are affected by many complex factors, including population trends, attitudes and aspirations (such as the increasing career interests of women), military draft regulations, employment outlook, and financial capability of the students. The availability or lack of Federal support for fellowships, traineeships, and training grants has an obvious, though not precisely measurable influence on graduate enrollments in science and engineering.

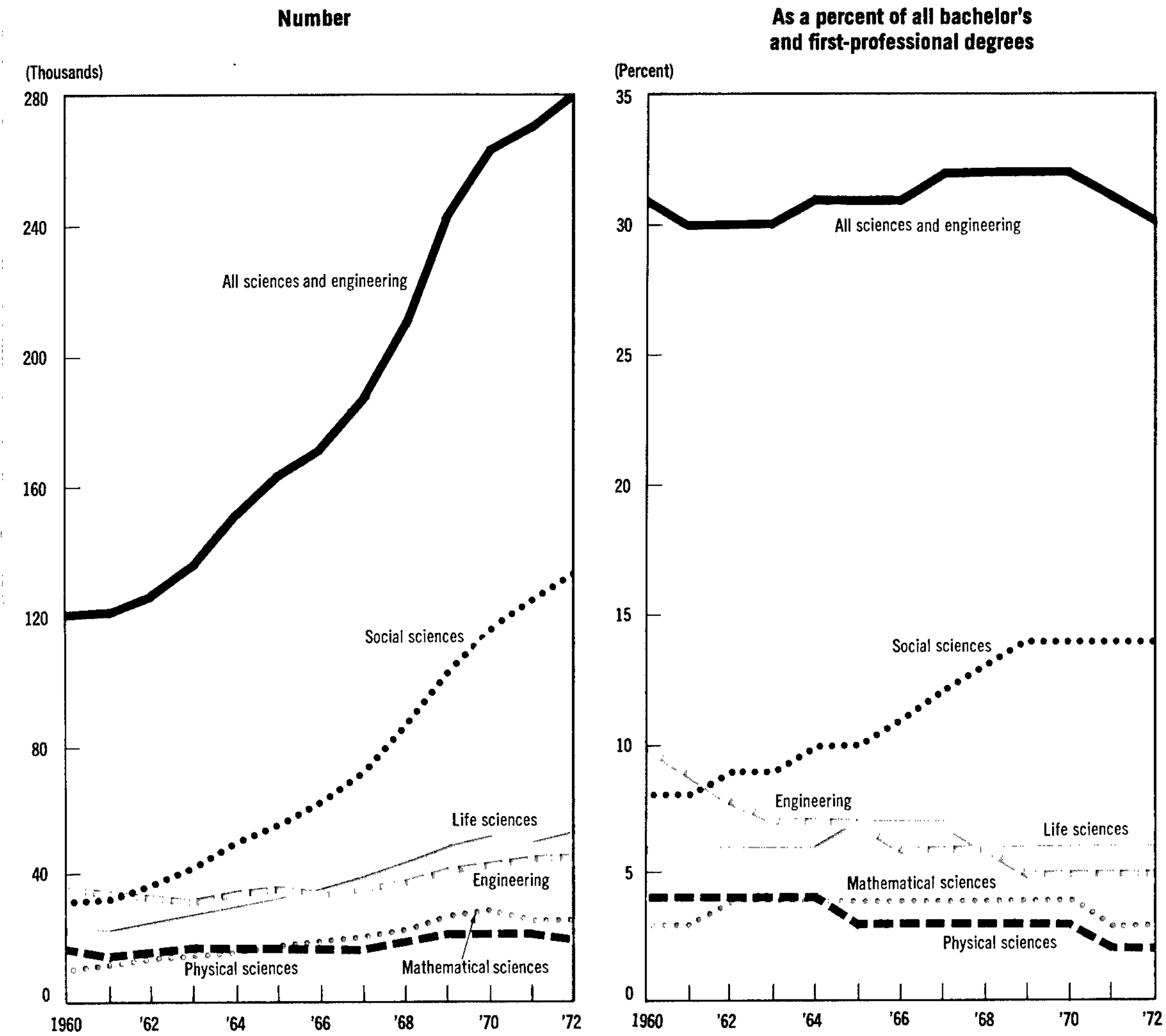
Enrollments for advanced degrees in science and engineering fields, as shown by annual data from the National Center for Educational Statistics, have grown considerably over the long term, doubling from 1960 to 1972 (figure 5-20). Within the science and engineering fields, engineering had the largest enrollment from 1960 through 1968, but declined in later years.

During the 1960-72 period, however, the most rapid growth in enrollment for advanced degrees occurred in fields other than science and

[35] M.D., D.D.S., D.V.M., etc.

Figure 5-19

Bachelor's degrees in science and engineering, 1960-72



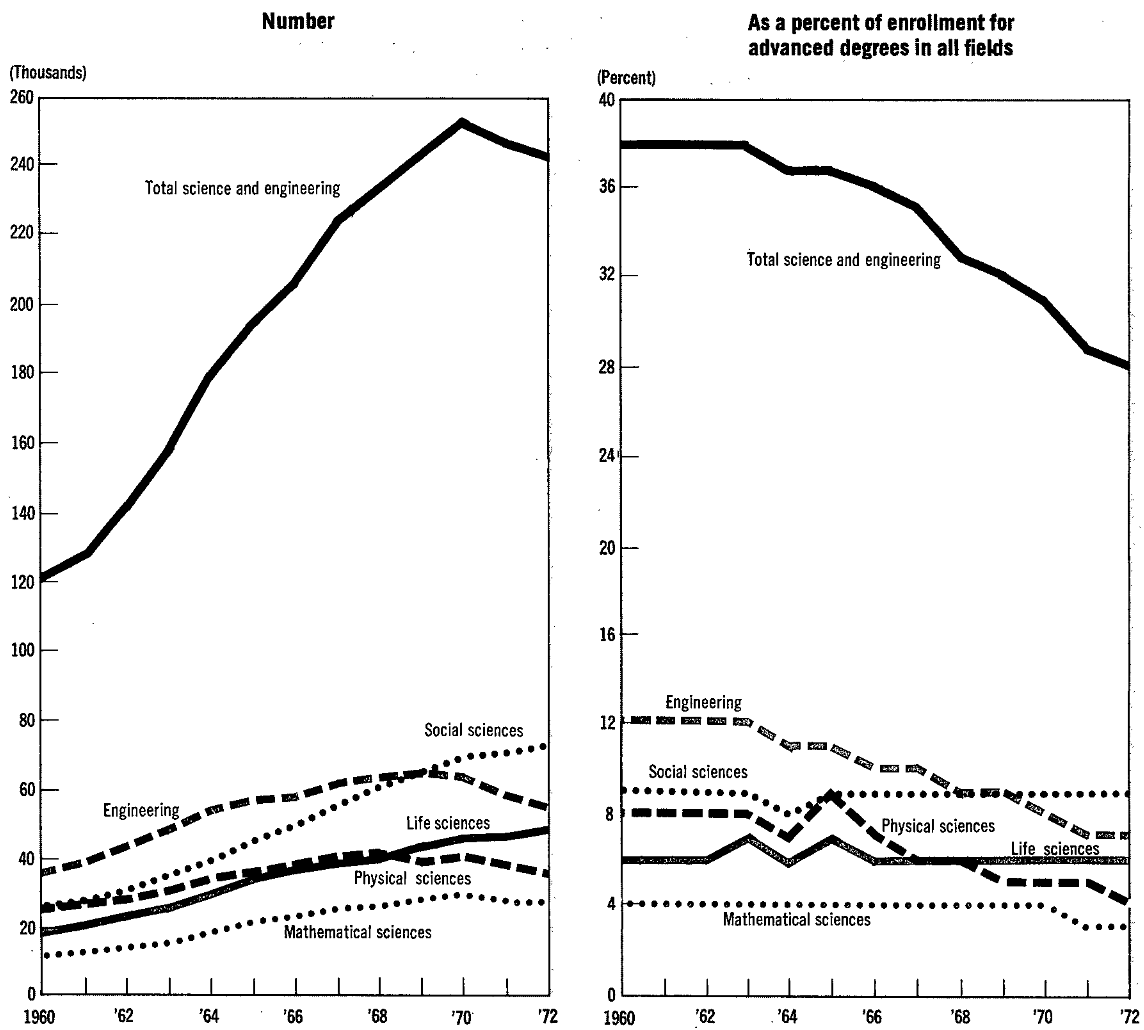
SOURCE: National Center for Educational Statistics and National Science Foundation.

engineering. As a result, enrollment for advanced degrees in science and engineering fields as a proportion of all advanced degree enrollment declined from 38 percent in 1960 to 28 percent in 1972 (figure 5-20). Engineering and the physical sciences accounted for most of this decline.

Related data, though not strictly comparable to those of the National Center for Educational Statistics, illustrate the direction of more recent trends in graduate enrollment. Data collected by NSF from institutions granting science and engineering doctorates indicate that the number of full-time graduate students in these fields decreased steadily from 1969 to 1974. Data from this fall 1974 survey indicate that full-time graduate science enrollment increased about 5 percent over fall 1973, the first increase since

Figure 5-20

Enrollment for advanced degrees in science and engineering, 1960-72



SOURCE: National Center for Educational Statistics and National Science Foundation.

1969. The life sciences accounted for almost all of the overall increase.[36]

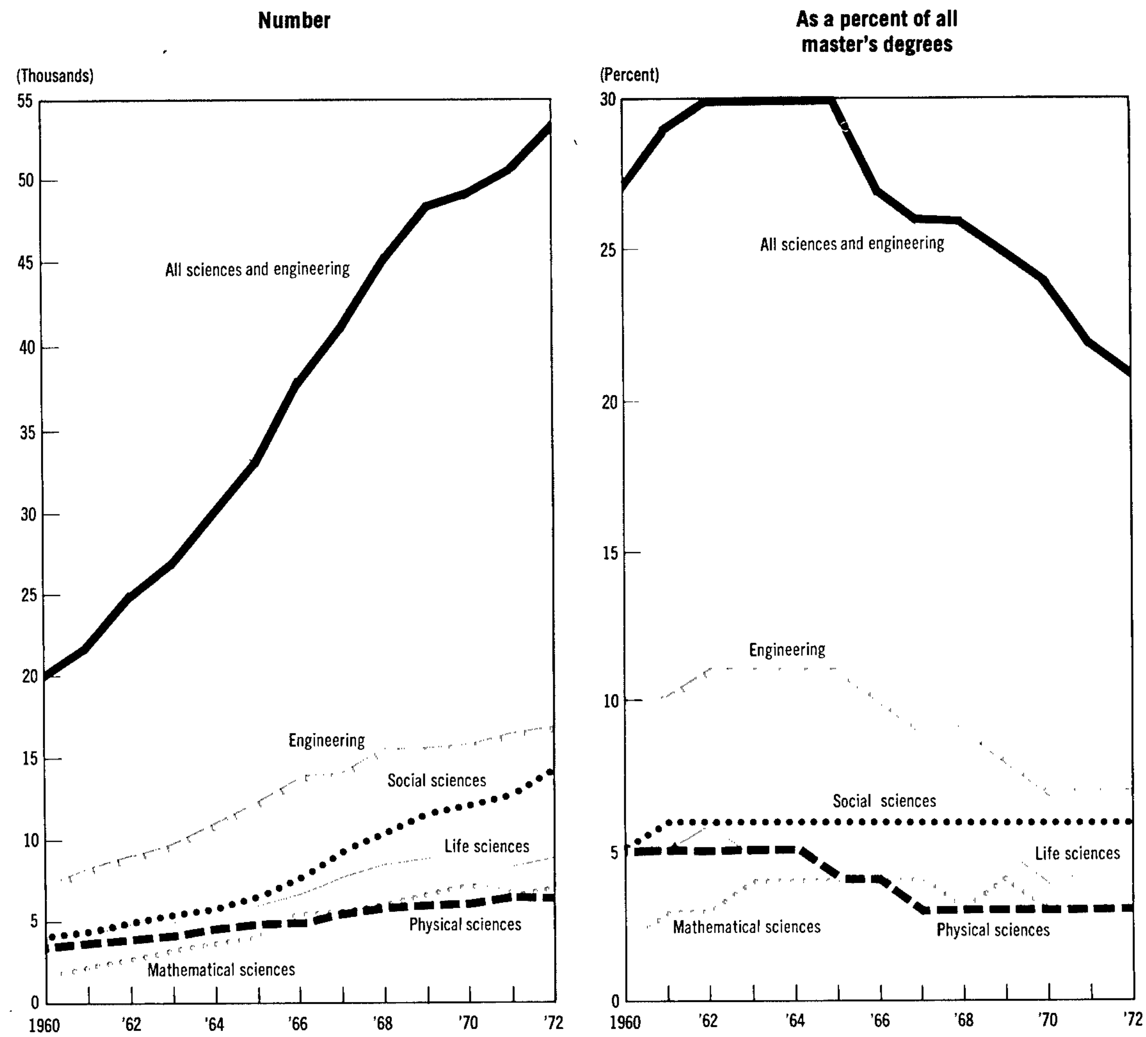
Master's degrees awarded

Annual awards of master's degrees in science and engineering for 1960 through 1972 are shown in figure 5-21. The number of these degrees awarded annually increased by over 150 percent between 1960 and 1972, with the largest percentage increases occurring in the mathematical sciences (307 percent) and the social sciences (263 percent), and the smallest in the physical sciences (86 percent). As a fraction of master's degrees in all fields, sciences and engineering degrees declined from a high of 30

[36] "Graduate Science Enrollment in 1974 Shows First Increase Since 1969", *Science Resources Studies Highlights*, National Science Foundation (NSF 75-328), October 22, 1975.

Figure 5-21

Master's degrees in science and engineering, 1960-72



SOURCE: National Center for Educational Statistics and National Science Foundation.

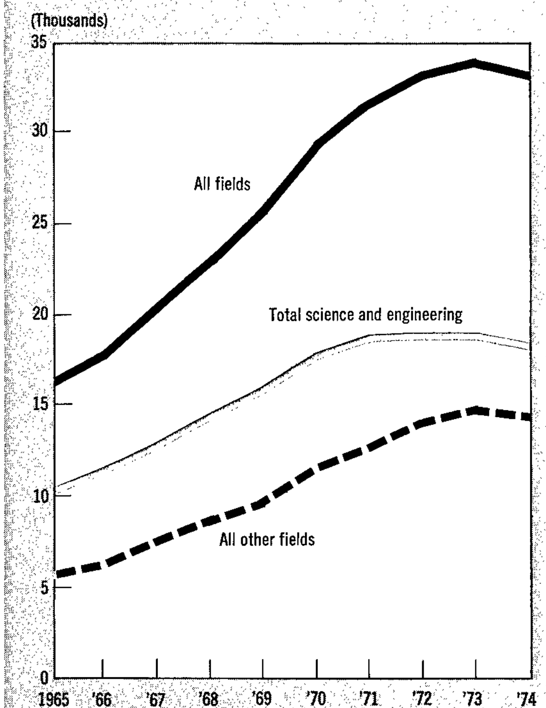
percent in 1965 to 21 percent in 1972; the largest proportional declines occurred in engineering and the physical and life sciences.

Doctoral degrees awarded

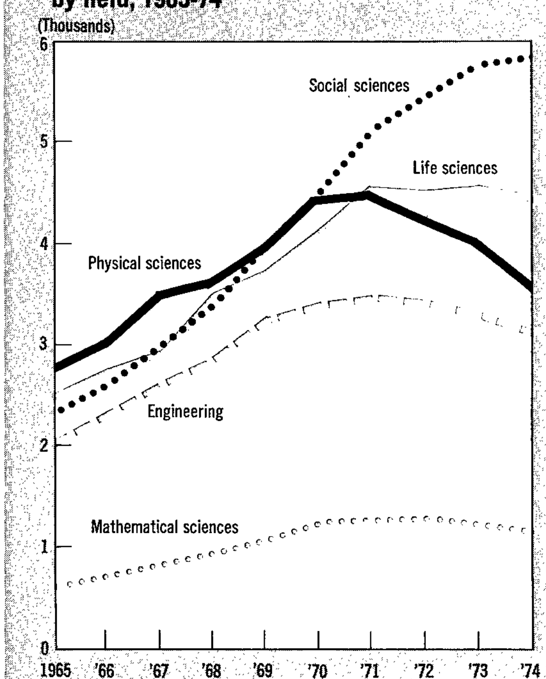
Annual awards of doctorates are shown in figure 5-22. Science and engineering degrees accounted for the majority of all doctorates awarded between 1965 and 1974, but their share fell from a high of 64 percent in 1964 to 56 percent in 1974. The number of men receiving doctoral degrees decreased in 1974, and although there was an increase in women doctorates it was not great enough to offset the drop for men.

Changes in major areas of science over the 1965-74 period are shown in figure 5-22. The physical sciences exhibited the slowest growth throughout the period and the largest decline in recent years; the number of physical science doctorates awarded dropped almost 20 percent from 1971 to 1974. Much of this decline is due to

Figure 5-22
Doctoral degrees awarded, 1965-74



Science and engineering doctorates, by field, 1965-74



SOURCE: National Academy of Sciences.

the sharp drop in physics and astronomy doctorate recipients, down 23 percent from 1971 through 1974, and to a nearly 20 percent decrease in chemistry doctorates over the same period.

Graduate student support

During the 1967-74 period, there were significant shifts in the patterns of support of graduate science students. In 1974, Federal support for full-time graduate science students in doctorate-granting institutions was provided at a level only slightly more than one-half that of 1967. While Federal support was being reduced, institutional and self-support increased, as shown in the table below.

Percent distribution of full-time graduate science students in doctorate departments, by source of major support, 1967 and 1974[37]

Major source of support	1967	1974
Federal support	42	25
Institutional support	34	40
Other outside support	10	9
Self-support	14	26

Among the various Federal programs for financial aid to graduate students, major reductions occurred in the number of awards for fellowships and traineeships.[38] By 1974, the number of graduate science students on federally supported fellowships and traineeships was reduced to approximately one-third of the 1967 level. There was also a decrease in the employment of graduate students on research projects, with the result that research assistants receiving Federal support declined by almost 20 percent during the same period. Since Federal R&D obligations to academic institutions rose 11 percent in constant dollars from the base year of 1967, it appears that occupational categories other than research assistants were given greater priority by these institutions.

There have been marked changes in patterns of Federal support of fellowships, traineeships,

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[37] *Graduate Student Support and Manpower Resources in Science Education, 1969,* National Science Foundation (NSF 70-40) and *Graduate Science Education: Student Support and Postdoctorals, Fall 1974,* National Science Foundation (NSF 75-322).

[38] *Graduate Science Education: Student Support and Postdoctorals,* National Science Foundation, annual series, and special tabulations.

and training grants in recent years.[39] Rather than providing direct student aid, there has been a tendency to rely more heavily on graduate student participation in federally funded research projects that support areas of national concern. Thus, Federal obligations for fellowships, traineeships, and training grants declined from $421 million in 1971 to $287 million in 1973. These funds rose again in 1974 to $327 million, largely because approximately $85 million of funds impounded in 1973 were released to HEW in 1974.

Among Federal agency programs affected by the shifts in funding were the Office of Education's student programs under the National Defense Education Act, NSF's traineeship program, and NASA's traineeship program. As a result, obligations by the Office of Education declined from $52 million in 1971 to $41 million in 1972, and after the termination of National Defense Education Act awards, to $10 million in 1973. NSF's support of fellowships and traineeships dropped from $42 million in 1971 to $16 million in 1973, and NASA's traineeship program was virtually eliminated.

Reductions in Federal support of fellowships, traineeships, and training grants were spread across all fields of science. The largest absolute decrease occurred in the life sciences, which dropped from $225 million in 1971 to $179 million in 1973.

Immigrant scientists and engineers

Another source of supply of scientists and engineers are those persons achieving immigrant status in the United States. Approximately 6,600 scientists and engineers immigrated to the United States in 1973. These numbers (see the table below) represent a reduction from the high 1966-72 yearly inflows resulting from revisions in October 1965 in the national immigration laws.

Scientists and engineers immigrating to the United States, annual average, 1949-73[40]

Period	Total	Engineers	Natural scientists	Social scientists
1949-65 ..	4,053	2,851	1,048	154
1966-72 ..	11,531	7,993	2,973	565
1973	6,632	4,443	1,790	399

[39] *Federal Support to Universities, Colleges, and Selected Nonprofit Institutions*, National Science Foundation, annual series.

[40] "Immigration of Scientists and Engineers Drops Sharply in FY 1973; Physician Inflow Still Near FY 1972 Peak", *Science Resources Studies Highlights*, National Science Foundation (NSF 74-302), March 29, 1974, and earlier reports of the series.

In February 1971, the existing system of "precertification" of prospective immigrants came to an end under U.S. Department of Labor regulations. This change did not bring about an immediate reduction in immigration because large numbers of foreign scientists and engineers, in anticipation of this legislation, had become precertified for immigration and eligible to enter the United States. There were enough of these scientists and engineers "in the pipeline" to maintain a high inflow of immigration through 1972, but the number of immigrant scientists and engineers has fallen sharply since that year.

Over the period 1966-68, the largest numbers of immigrant scientists and engineers came to the United States from developed nations. After that time, the situation changed, with by far the largest numbers coming from the developing nations.

WOMEN AND MINORITIES IN SCIENCE AND ENGINEERING

Women employed in science and engineering

Increasing interest has been expressed in recent years in the opportunities for participation of women in science and engineering. Despite the widespread interest, however, relatively little information is available on the subject, particularly those that allow the examination of trends over time. This section presents some data concerning the employment of women in science and engineering occupations, women receiving doctorates in these areas, and women enrolled for advanced degrees in the sciences and engineering.

In 1974, women comprised 5 percent of the persons employed in science and engineering occupations, compared with 39 percent of the total civilian work force, and 41 percent of the professional and technical workers.[41] Large differences exist in the level of employment of women among the various fields of science and engineering, as shown in the table below.

[41] The category of professional and technical workers includes occupations such as accountant, lawyer, nurse, physician, and teacher. In 1970 (the most recent year for which comparable data are available), the proportions of all lawyers who were women (5 percent) and the proportion of all physicians who were women (9 percent) were relatively similar to that for scientists and engineers (5 percent).

Percent distribution of women scientists and engineers, by field, 1974[42]

Field	Percent of total
Psychologists	28
Social scientists	21
Mathematical scientists	15
Life scientists	13
Computer scientists	12
Physical scientists	8
Environmental scientists	3
Engineers	1

Women scientists and engineers were most likely to be involved in psychology and the social sciences, and least likely to work in engineering and in the environmental and physical sciences.

A somewhat different pattern of employment of women scientists and engineers exists in the academic sector. In 1974, 15 percent of the scientists and engineers employed full-time[43] at colleges and universities were women; 16 percent of the scientists and 1 percent of the engineers. The proportion of women in each field of science varies widely, as shown in the table below.

Women comprise 21 percent of both the life scientists and the psychologists, but less than 10 percent of both the physical and environmental scientists. In the case of doctorate-granting institutions alone, the level of employment of women is somewhat lower than in colleges and universities as a whole.

Women in graduate education

An increasing number of women are pursuing advanced studies in science and engineering (figure 5-23). Between 1965 and 1974, the number of women receiving doctoral degrees in science and engineering increased by almost 250 percent, from 744 to 2,590. This absolute growth also represents an increase in the share of science and engineering doctorates earned by women, the proportion growing from 7 percent in 1965 to 14 percent in 1974. By 1974, women were awarded 24 percent of the doctorates in the social sciences, and 18 percent in the life sciences, but 10 percent or less in the mathematical sciences, physical sciences and engineering.[46] The proportion of women students enrolled for

Full-time women scientists and engineers employed by universities and colleges, by field, 1974[44]

Field	All institutions		Doctorate institutions	
	Number of women	Percent women in each field	Number of women	Percent women in each field
All scientists and engineers	35,083	15	20,896	14
Engineers	311	1	260	2
Physical scientists	1,912	7	801	5
Chemists	1,378	10	526	7
Physicists	392	4	197	3
Other physical scientists	142	7	78	6
Environmental scientists[45]	319	5	195	5
Mathematical scientists	2,825	13	856	9
Life scientists	19,264	21	14,605	19
Agriculture	1,796	13	1,757	15
Biological	5,550	18	3,379	16
Medical	11,918	25	9,469	22
Psychologists	3,067	21	1,132	17
Social scientists	7,385	15	3,047	13

[42] National Science Foundation, special tabulations.

[43] Data for part-time women scientists and engineers are not available.

[44] *Manpower Resources for Scientific Activities at Universities and Colleges, January 1974,* Detailed Statistical Tables, National Science Foundation (NSF 75-300-A).

[45] Includes earth scientists, oceanographers, and atmospheric scientists.

[46] For further, more recent information on this topic see Joseph L. McCarthy and Dael Wolfle, "Doctorates Granted to Women and Minority Group Members", *Science,* Vol. 189, (1975), pp 856-859.

advanced degrees in science and engineering, as reported by the Office of Education, also increased markedly, by 73 percent overall between 1966 and 1972. In 1972 (the latest year for which data are available) women represented varying proportions of the total enrollments of each of the fields below.

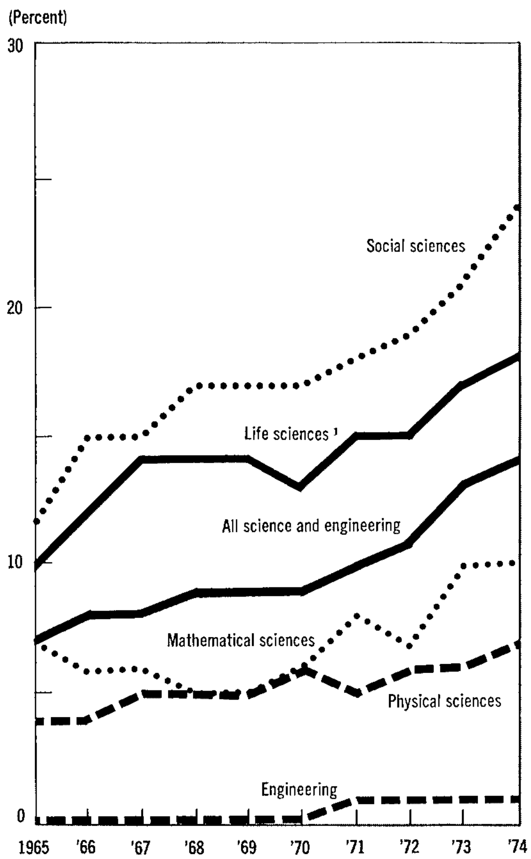
Proportion of women enrolled for advanced degrees, by field, 1966 and 1972

Field	Percent of total	
	1966	1972
All science and engineering fields ...	13	19
Social sciences	24	31
Life sciences	20	24
Mathematical sciences	18	22
Physical sciences	8	12

One factor which may affect the participation of women in science and engineering is the substantial difference in salary levels for men and women in science occupations. Among doctoral scientists and engineers, the 1973 median salary for women ($17,600) was 17 percent lower than that for men ($21,200). Women's salaries are consistently below men's at each age level, but the gap widens considerably after age 40.[47]

Figure 5-23

Women as a percent of total science and engineering doctorate recipients, by field, 1965-74



¹ Includes environmental sciences.
SOURCE: National Academy of Sciences.

Racial minorities in science and engineering

Information concerning the racial identification of members of the scientific community has been made available only in recent years. Data are presented here concerning the racial composition of the national pool of scientists and engineers, the characteristics of minority doctoral scientists and engineers by field, and the representation of minority students in each field of graduate science study.

Caucasians represent the predominant portion of all scientists and engineers (96 percent); those of Asian background account for over 2 percent, Blacks comprise about 1 percent, and other nonwhites (e.g., American Indians) the remainder (figure 5-24).

The field of mathematics has the largest proportion of racial minorities (8 percent), followed by the physical sciences (6 percent) and the life sciences (6 percent). Blacks have the highest level of participation in mathematics,

[47] *Doctoral Scientists and Engineers in the U.S., 1973 Profile,* National Academy of Sciences, 1974.

representing 5 percent of all mathematicians, Orientals in the physical sciences (4 percent), and other races in the life sciences (1 percent). The largest absolute number of minorities, by total and for each group, are found in engineering, although minorities have the smallest proportional representation in this field.

The representation of minorities among doctoral scientists and engineers in 1973 is shown in the table below.[48]

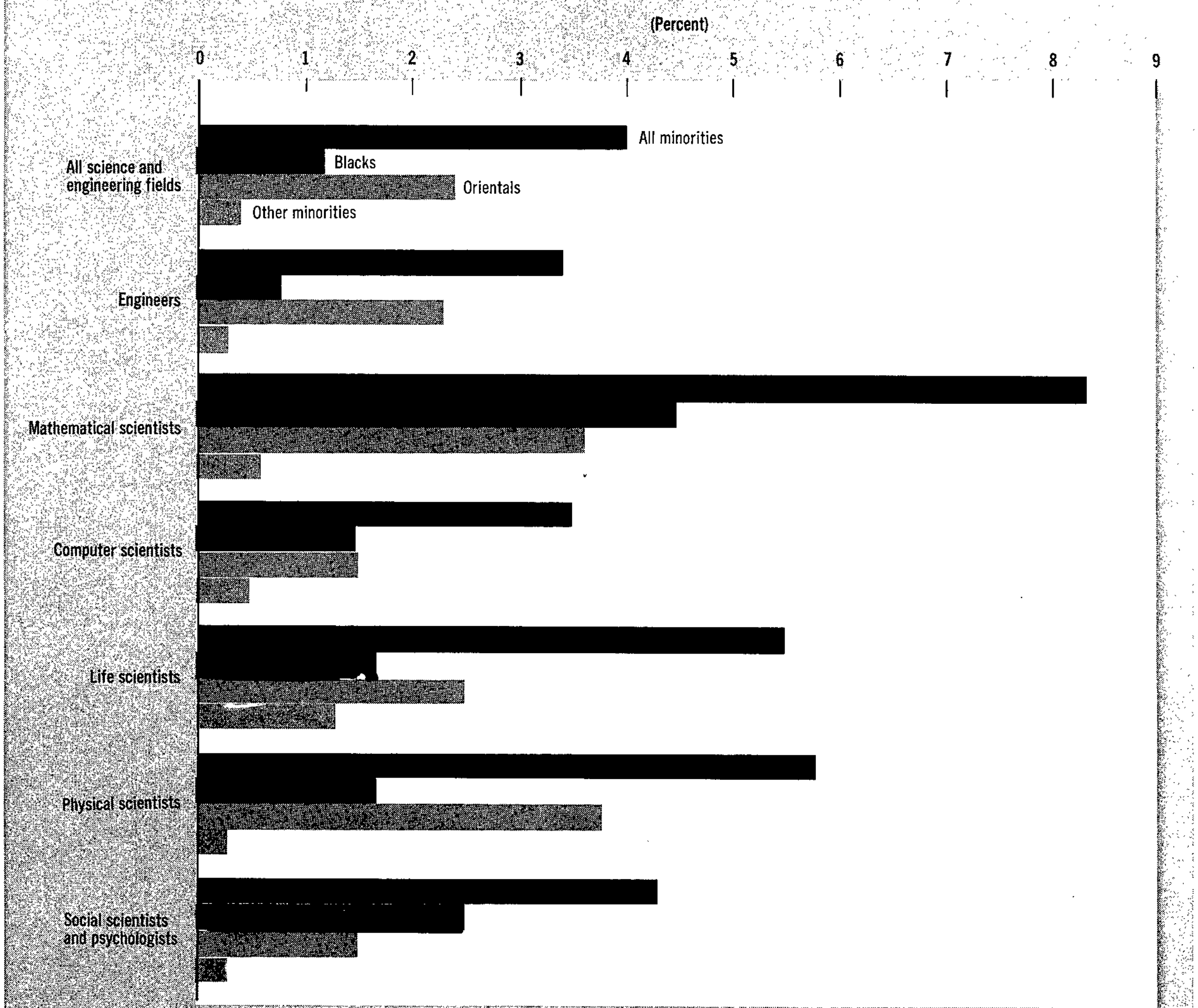
[48] *Characteristics of Doctoral Scientists and Engineers in the United States, 1973,* National Science Foundation (NSF 75-312).
[49] Less than 0.05 percent.

Proportion of minority doctoral scientists and engineers, by field, 1973

Field	Percent in each field: Black	American Indian	Asian
All scientists and engineers	0.8	([49])	4.5
Physical scientists	.8	([49])	4.7
Mathematical scientists	.8	NA	4.8
Environmental scientists	.2	NA	2.8
Engineers	.2	([49])	8.4
Life scientists	.9	([49])	4.3
Psychologists	.9	([49])	1.1
Social scientists	1.1	.1	3.6

Figure 5-24

Minority representation among scientists and engineers, by field, 1972



SOURCE: National Science Foundation.

Among the black doctoral scientists and engineers, the largest proportion is involved primarily in teaching activities (40 percent), followed by administration (19 percent), and research and development (16 percent). This pattern of activity applies in each of the fields. Black doctoral scientists and engineers are employed for the most part by universities and four-year colleges (61 percent), with the next largest proportions employed by industry (13 percent) and the Federal Government (7 percent). This pattern is consistent across all fields. In comparison, about one-half of the white doctoral scientists and engineers are employed by universities and four-year colleges, with the next largest proportion (21 percent) employed by industry, and 8 percent employed by the Federal Government. Doctoral scientists and engineers who are American Indians also are primarily involved in teaching (69 percent) and employed by universities and four-year colleges.

Asian doctoral scientists and engineers exhibit quite different characteristics. They are primarily involved in research and development (41 percent), teaching (29 percent), and administration (7 percent). Compared with the other minorities, a greater proportion of Asians are employed by industry: 51 percent in universities and four-year colleges, 28 percent in industry, and 5 percent in the Federal Government.

These data suggest that there are characteristic patterns of involvement in science for selected minorities. Black scientists and engineers, for example, tend to be involved in social science and health science fields, and predominantly in teaching activities. In contrast, Asian Americans tend toward the physical sciences and engineering, and involvement in R&D activities.

An indication of the current participation of minority students in science and engineering graduate study is presented in the following table.[50] It should be pointed out that these data do not represent national totals, but they were reported by a significant proportion of doctorate-granting institutions.

Proportion of minorities in science and engineering graduate studies, by field, 1973

	Percent in each field		
Field	Black	American Indian	Asian
All science and engineering	2.5	0.3	2.1
Physical sciences	1.4	.2	2.6
Mathematical sciences	2.5	.2	2.1
Engineering	1.2	.1	3.3
Life sciences	1.5	.2	1.9
Health professions	5.5	.6	2.0
Social sciences and psychology	4.1	.3	1.1

In analyzing the proportion of black students enrolled in each field, it is apparent that the health professions and social sciences attract the largest percentage of black graduate students, while engineering, physical sciences, and life sciences attract the lowest proportion. In contrast, the Asian graduate students enroll in higher proportions to study engineering and the physical sciences, and are less involved in the social sciences.

[50] Elaine H. El-Khawas and Joan L. Kinzer, *Enrollment of Minority Graduate Students at Ph.D.-Granting Institutions*, (Washington, D.C.: American Council on Education, 1974).

Public Attitudes Toward Science and Technology

Public Attitudes Toward Science and Technology

INDICATOR HIGHLIGHTS

- The belief that science and technology have changed life for the better was expressed by 75 percent of the public in 1974, compared with 70 percent in 1972; 5 percent saw the change as for the worse, down from 8 percent in 1972.
- In the public's ranking of nine professions and occupations, scientists were second only to physicians in both 1972 and 1974, with engineers in third place.
- Science and technology were believed to have done "more good" than "more harm" by 57 percent of the people in 1974, compared with 54 percent in 1972; 31 percent in both years saw the impact as about evenly divided between good and harm.
- Among people who believe science and technology do more good than harm, the largest group (59 percent in 1974 and 54 percent in 1972) cited improvements in medicine and medical research as the leading benefit; among those having the view that science and technology do more harm than good, "lack of concern for the environment" was the most frequently mentioned example (25 percent in 1974 and 27 percent in 1972).
- Science and technology were thought to have caused some of our problems by approximately half of the respondents in both 1972 and 1974; a smaller group (approximately 37 percent) believed that few or none of our problems were so caused, while a still smaller group (less than 8 percent) thought that science and technology were responsible for most of the problems.
- The pace of change produced by science and technology was viewed as "about right" by some 50 percent of the public in both 1972 and 1974, as too fast by about 20 percent of the people, and as too slow by a slightly smaller percentage.
- The public expects science and technology to solve, eventually, many of our major problems, although the fraction expecting most problems to be so solved declined from 30 percent in 1972 to 23 percent in 1974.
- Areas in which the public felt they would most like to have taxes spent for science and technology were health care, crime reduction, education, prevention of drug addiction, and pollution control; areas in which they would least like to have taxes spent for science and technology were "space exploration" and "developing and improving weapons for national defense."
- Demographic analysis of selected questions in the survey suggests that the most positive attitudes toward science and technology were held by men, persons between 30-59 years of age, those with some college education, and by people whose family income was $10,000 or more.

Public attitudes affect science and technology in many ways. Public opinion sets the general environment and climate for scientific research and technological development. It is influential in determining the broad directions of research and innovation, and through the political process, the allocation of resources for these activities. In addition, public attitudes toward scientists and engineers and their efforts affect the career choices of the young by influencing their decision to enter these fields.

The survey of public attitudes toward science and technology summarized in *Science Indicators—1972* was repeated for this report.[1] The 1974 replication of the earlier survey serves both as a check on the findings of the previous survey and as the beginning of a time series of data for tracking trends in attitudes and opinions.

A personal interview survey was conducted in July and August 1974 among 2,074 persons 18 years of age and older. The sampling techniques used in the survey permit the results to be projected to the entire U.S. population.

The survey was designed to explore three aspects of public attitudes and opinions: the public's regard for science and technology; the public's sense of the impact of those activities; and the public's expectations and desires regarding the role of science and technology in dealing with national problems. Results are reported first for the total sample of respondents, and then for demographic groups.

TOTAL GROUP RESPONSES

Public regard for science and technology

Three aspects of attitudes were explored under this heading: how the public feels science and technology have affected the quality of life; the general emotional reaction associated with science and technology; and where scientists and engineers rank in prestige among nine professions and occupations.

[1] Both surveys were conducted by the Opinion Research Corporation, Princeton, N.J. For more complete information concerning the survey results and methodology, including a description of the reliability of the results and the differences required for statistical significance, see: *Attitudes of the U.S. Public Toward Science and Technology, Study II,* Opinion Research Corporation, 1974 (A study commissioned specifically for this report).

In 1974, 75 percent of the public felt that science and technology have changed life for the better, compared with 70 percent in 1972. This gain is concurrent with a decline in the "worse" and the "no opinion" responses.

Do You Feel That Science and Technology Have Changed Life for the Better or for the Worse?

Response	*Percent* 1972	1974
Better	70	75
Worse	8	5
Both	11	11
No effect	2	3
No opinion	9	6

The reaction of "satisfaction or hope" to science and technology was expressed by 56 percent of the people in 1974, versus 49 percent in 1972. In both years, a reaction of "excitement or wonder" was shared by 22 to 23 percent of the public. Fewer respondents expressed "No opinion" in 1974 than in 1972.

Which One of These Items Best Describes Your General Reaction to Science and Technology?

Response	*Percent* 1972	1974
Satisfaction or hope	49	56
Excitement or wonder	23	22
Fear or alarm	6	5
Indifference or lack of interest	6	7
No opinion	16	11

For a further indication of the regard for science and technology, people were asked to rate each of nine professions and occupations in terms of the "prestige or general standing that each job has." The rating categories used were "excellent," "good," "average," "below average," and "poor." These categories were assigned weights, and the resulting rankings are shown below, not only for the 1972 and 1974 surveys but also for comparable studies in 1947 and 1963.

Rankings of Occupations

	1947[a]	*1963*[a]	*1972*	*1974*
Physician	1	1	1	1
Scientist	2	2	2	2
Engineer	7	6	3.5	3
Minister	4	5	3.5	4
Architect	5.5	4	6.5	5
Lawyer	5.5	3	5	6
Banker	3	7	6.5	7
Accountant	9	8	8	8
Businessman	8	9	9	9

[a] R. W. Hodge, *et al.*, "Occupational Prestige in the United States, 1925-63," *American Journal of Sociology*, Vol. 70 (1964), pp. 286-302.

In both 1972 and 1974, scientists held their relative ranking among occupations, second only to physicians, with engineers third. Against 1963 ratings, all occupations remained lower in both 1972 and 1974.

Impact of science and technology

This part of the survey explored several facets of the impact of science and technology as perceived by the public, including whether the overall impact is more positive than negative; identification of the science and technology activities which the public regards as good or harmful; the extent to which it feels science and technology cause problems; and whether the pace of change induced by science and technology is desirable. Following these questions, the public was asked to assess the adequacy of control that is exercised over science and technology.

Slightly more than half of those interviewed believed that science and technology do more good than harm. About one-third saw the extent of good and harm as being nearly the same, and only a negligible percentage said "more harm." Changes from 1972 to 1974 were slight.

Overall, Would You Say That Science and Technology Do More Good Than Harm, More Harm Than Good, or About The Same Each?

Response	*Percent* 1972	1974
More good	54	57
About the same	31	31
More harm	4	2
No opinion	11	10

Those responding "more good than harm" or "about the same" were asked, without prompting, to mention some "good thing" they thought science and technology had done, and the responses were then categorized. The results summarized below show that "medical advances" was by far the most frequently mentioned benefit, followed by "new and improved products" and "space research".

Benefits from Science and Technology (Cited by group responding "More good than harm")

Response	*Percent citing*[a] 1972	1974
Medical advances	54	59
New and improved products	10	11
Space research	12	9
Environment and natural resources	6	4
Living and working conditions	5	3
Food and agriculture	4	2
Energy	1	2
Other	4	6
Don't know	4	4

Benefits from Science and Technology (Cited by group responding "About the same")

Response	*Percent citing*[a] 1972	1974
Medical advances	50	48
New and improved products	8	15
Space research	9	9
Living and working conditions	5	6
Environment and natural resources	6	5
Food and agriculture	3	2
Energy	(b)	2
Other	3	6
Don't know	17	19

[a] Multiple responses were accepted.
[b] Less than 0.5 percent.

The group which believed that science and technology do about equal amounts of good and harm was asked, without prompting, to mention "one of the harmful things." These results, summarized below, show that "lack of concern for the environment" was most frequently mentioned as harmful, followed by "development of military weapons," "space research," and "dangerous drugs and medicines." Almost one-third of this group failed to offer an example of a harmful result from science and technology, whereas less than 20 percent of the same group failed to provide an example of a "good" result. (See the table just above).

Harmful Effects of Science and Technology (Cited by group responding "About the same")

Response	Percent citing[a] 1972	1974
Lack of concern for the environment	27	25
Development of military weapons	9	11
Space research	16	9
Dangerous drugs and medicines	3	9
Depletion of natural resources	2	2
Other	16	19
Don't know	27	32

[a] Multiple responses were accepted.

As shown in the following three tables, the public's views remained stable over the 1972-74 period on questions regarding the relationship of science and technology with society.

Science and technology are thought to cause some of today's problems by about half the public, and as the source of few or none of the problems by some 40 percent.

Do You Feel that Science and Technology Have Caused Most of our Problems, Some of our Problems, Few of our Problems, or None of our Problems?

Response	Percent 1972	1974
Most	7	6
Some	48	50
Few	27	29
None	9	9
No opinion	9	6

A slight majority of the public continued to feel that science and technology produce change at a pace "about right". Remaining opinion is almost evenly divided between "too fast" and "too slowly".

Do You Feel That Science and Technology Change Things Too Fast, Too Slowly, or Just About Right?

Response	Percent 1972	1974
Too fast	22	20
About right	51	53
Too slowly	16	18
No opinion	11	9

Almost half of those polled felt that the extent of control society should have over science and technology should "remain as it is," and nearly 30 percent felt that greater control was needed.

Do You Feel That the Degree of Control that Society Has Over Science and Technology Should be Increased, Decreased, or Remain As It is Now?

Response	Percent 1972	1974
Should be increased	28	28
Remain as it is	48	46
Should be decreased	7	8
No opinion	17	18

Expectations and directions for science and technology

About three-fourths of the public remained confident that science and technology will eventually solve at least some of the major problems, examples of which were named in the question. But the expectation that most problems would yield to such solution declined, falling from 30 percent in 1972 to 23 percent in 1974. The trend toward a lower level of confidence is evident in the larger percentage of those who expect science and technology to solve only "some" and "few" such problems.

Do You Feel That Science and Technology Will Eventually Solve Most Problems Such as Pollution, Disease, Drug Abuse, and Crime, Some of These Problems, or Few, if Any of These Problems?

Response	Percent 1972	1974
Most problems	30	23
Some problems	47	53
Few problems	16	20
No opinion	7	4

Areas in which the public would "most like" to see their tax money for science and technology spent are "health care," "reducing crime," "reducing and controlling pollution," "preventing and treating drug addiction," and "improving education."[2] Two major shifts in public preferences occurred in these areas between 1972 and 1974: "reducing and controlling pollution" declined considerably in the frequency of selection, whereas "improving education" increased. Among the less highly ranked areas,

[2] Selection was made from a list of 12 areas snown in the next tabulation.

"improving the safety of automobiles" fell from the choice of 38 percent of the public in 1972 to 29 percent in 1974.

Areas in which the public in 1974 indicated they would least like their taxes spent for science and technology were "space exploration," and "developing or improving weapons for national defense."

period. An increasingly large percentage of the public believed that science and technology had changed life for the better; a substantial and growing fraction expressed a feeling of satisfaction and hope with respect to science and technology; and scientists and engineers received high rankings among other occupations and professions, although the rankings of all groups were relatively high.

In Which of the Areas Listed Would You Most Like (and Least Like) to Have Your Taxes Spent for Science and Technology?

Response	*Percent choosing area*[a]			
	Most like		*Least like*	
	1972	*1974*	*1972*	*1974*
Improving health care	65	69	1	1
Reducing and controlling pollution	60	50	3	3
Reducing crime	59	58	2	2
Finding new methods for preventing and treating drug addiction	51	48	4	4
Improving education	41	48	4	3
Improving the safety of automobiles	38	29	5	8
Developing faster and safer public transportation for travel within and between cities	23	26	14	13
Finding better birth control methods	20	18	18	23
Discovering new basic knowledge about man and nature	19	21	15	14
Weather control and prediction	11	14	19	16
Space exploration	11	11	42	37
Developing or improving weapons for national defense	11	11	30	30
No opinion	6	3	13	7

[a] Multiple responses were accepted.

These opinions should be interpreted with caution. The relevance of science and technology for alleviating or solving the problems involved was not considered explicitly. Thus, the responses may reflect areas of general concern to the public without regard for the possible specific role of science and technology in dealing with them. Furthermore, the actual words used in describing the various areas may have a biasing effect; e.g., the word "weapons" in "developing or improving weapons for national defense" may have a negative connotation which accounts in part for the low preference for science and technology in this area.

Summary of the total group responses

The results of the survey provide reasonably clear answers to the three general questions addressed to the public. The regard for science and technology appears to be relatively high and to have grown slightly during the 1972-74

The results regarding the impact of science and technology are somewhat less positive, and differ little in the two surveys. A small majority expressed the belief that science and technology overall did more good than harm—although they were held responsible for at least some of our problems—while almost one-third thought the impact was about equally divided between beneficial and harmful effects. The extent of social control over science and technology, however, should remain as it is according to almost half those surveyed, whereas the need for greater control was expressed in nearly 30 percent of the responses.

The predominant expectation is for considerable achievement by science and technology in solving major problems, even though the level of expectation declined somewhat between 1972-74. In both years, slightly more than 75 percent of those surveyed expected science and technology to solve some or most of our current problems.

DEMOGRAPHIC RESPONSES

The responses of demographic groups, although similar, were not identical. Examination of these differences is limited in this report to two of the questions covered in the survey. The pattern of responses to these two is similar to the attitudes and opinions expressed by the demographic groups to the other survey questions.

The response of "no opinion" is relatively high in all groups,[3] but is especially so among the oldest, lower income, and least educated subgroups. Such responses mask differences in expressed opinion toward science and technology and for this reason, comparisons of subgroups in the following two tables are based on percentages of those expressing an opinion.

Differences of sex and age

Responses of men were somewhat more positive than women to science and technology in both questions. Men appear to judge past contributions of science and technology more favorably, and to express more confidence in future accomplishments. Both groups, however, were less confident in 1974 that science and technology would "eventually solve most problems."

In general, people between 30-59 years of age expressed the most favorable attitudes toward science and technology, followed by the young (18-29 years), and the older group (60 and above). All age groups recorded less confidence in 1974 in expecting problems to be solved by science and technology. (Major differences between responses of the youngest group and those of the total are noted below for all questions in the survey.)

Differences in education and family income

Attitudes and opinions toward science and technology appear to correlate closely with education: the greater the amount of formal education, the more favorable the response. For example, 54 percent of those with less than a high school education felt in 1974 that science and technology do more good than harm, compared with 67 percent of those who had completed high school, and 71 percent of those with some college education.

Attitudes and family income appear to correlate to some extent on both the overall impact of science and technology and future contributions toward solving problems. Some 70

Overall, Would You Say That Science and Technology Do More Good Than Harm, More Harm Than Good, or About the Same of Each?

Percentage of group expressing

	"More good"		"About same"		"More harm"		"No opinion"	
	1972	*1974*	*1972*	*1974*	*1972*	*1974*	*1972*	*1974*
All	61	63	35	35	4	2	11	10
Men	64	67	32	31	4	2	8	8
Women	59	59	38	39	3	2	13	12
18-29 yrs.	55	59	39	38	5	3	8	4
30-39	69	71	29	28	2	1	7	10
40-49	66	64	29	33	5	3	7	8
50-59	60	67	35	31	4	2	9	8
60 +	57	55	39	41	4	4	19	20
Less than high school	51	54	43	43	6	3	18	19
High school	63	67	35	31	2	2	5	4
Some college	74	71	22	27	4	2	5	4
Family income:								
Under $5,000	44	56	39	41	7	3	18	21
$5,000-$6,999	47	53	40	41	4	6	16	10
$7,000-$9,999	54	59	34	39	6	2	10	7
$10,000-$14,999	61	71	34	28	2	1	4	5
$15,000 or over	71	69	27	30	2	1	3	6

[3] A high frequency of "no opinion" responses occurs typically in surveys concerned with science and technology, as discussed in Amitai Etzioni and Clyde Nunn, "The Public Appreciation of Science in Contemporary America," *Daedalus*, Vol. 103 (1974), pp. 191-206.

percent of those with a family income of $10,000 or more in 1974 felt that science and technology do more good than harm, compared with an average of 58 percent for the groups having a lower income. With regard to solving problems in the future, groups with higher incomes tended to expect solutions from science and technology to a greater extent than the lower income groups. All groups generally expressed more satisfaction with science and technology in 1974 than in 1972, but felt less confident in their ability to solve major problems in the future.

in prestige than did the total sample. On the other hand, a somewhat larger percentage of the young in both surveys felt that science and technology have caused some of our problems--56 percent versus 50 percent of the total sample in 1974.

There are other differences, however, between the young and the total sample, but these do not bear so directly on matters or attitudes as on differences in concern and priority. The young in both surveys expressed

For The Most Part, Do You Feel That Science and Technology Will Eventually Solve Most Problems Such as Pollution, Disease, Drug Abuse, and Crime, Some of These Problems, or Few if Any of These Problems?

	Percentage of group expressing							
	"Most"		*"Some"*		*"Few"*		*"No opinion"*	
	1972	*1974*	*1972*	*1974*	*1972*	*1974*	*1972*	*1974*
All	32	24	51	55	17	21	7	4
Men	36	26	47	54	17	20	5	2
Women	29	23	54	59	18	20	9	5
18-29 yrs.	28	24	55	56	17	20	5	2
30-39	33	25	54	59	13	16	3	3
40-49	31	25	53	56	16	19	4	3
50-59	37	27	43	53	20	20	7	2
60 +	33	22	46	53	21	25	13	9
Less than high school	33	21	47	54	20	25	12	8
High school	29	25	55	56	16	19	4	2
Some college	35	28	51	58	14	14	3	1
Family income:								
Under $5,000	35	22	47	51	18	27	14	8
$5,000-$6,999	23	24	57	52	20	24	6	5
$7,000-$9,999	33	24	49	58	18	18	6	2
$10,000-$14,999	33	25	52	56	15	19	3	3
$15,000 or over	33	26	51	59	16	15	1	1

Attitudes of the young

The belief that young people of the Nation have negative attitudes toward science and technology gained considerable credence beginning in the late 1960's. To examine the current validity of this belief, responses of the young (18-29 years of age) to all questions of the survey were compared with responses of the total sample.

For the most part, attitudes of the young were closely similar to those of the total sample. Major differences from the sample as a whole were found in only two areas, one of which suggests a more positive attitude toward science and technology on the part of the young, whereas the other indicates a more negative assessment. In the first case, the young group (in both 1972 and 1974) rated "scientists" significantly higher

consistently more concern for the environment. The reduction and control of pollution was specified by 60 percent of the young group in 1974 as an area where they would most like to see their tax dollars spent, compared with 50 percent for the sample as a whole. "Lack of concern for the environment" was listed in 1974 as one of the "harmful" effects of science and technology by 31 percent of the young versus 25 percent of the total sample.

The young differed from the total sample in 1974 in their choice of areas for efforts in science and technology. "Improvement of education" was selected by 58 percent of the young compared with 48 percent of the total sample; "discovering new basic knowledge" was chosen by 29 percent versus 21 percent; and "finding better birth control methods" was selected by 25 percent versus 18 percent. In listing "least liked"

areas for expenditures, 45 percent of the young group cited "developing and improving weapons for national defense," as against 30 percent of the total group. Similarly, "weather control and prediction" was cited as "least liked" by 24 percent of the group versus 16 percent of the total sample.

OTHER SURVEYS

Surveys on public attitudes toward science and technology were recently reviewed by Etzioni and Nunn.[4] Results from the survey conducted for this report appear to be consistent with earlier studies, to the extent that direct comparisons can be made.

The results of the present survey (1972 and 1974) with respect to the public's general regard for science may be placed in a broader context by reference to comparable surveys: a Harris poll in 1972 and one by the National Opinion Research Center (NORC) in 1973 and a replication in 1974. These surveys explored levels of public confidence in "the people who are running" 11 institutions.[5] In the Harris Poll, science as an institution ranked second among the 11 in terms of the percentage of the public indicating "a great deal of confidence." In 1973, the NORC survey[6] also showed science ranking second, with education, in public confidence. The percentage expressing a great deal of confidence in science rose from 37 to 45 in 1974, but because of an even larger gain for education, from 37 to 49, the rank of science dropped to third among the 11 institutions in 1974.

A more recent survey by LaPorte and Metlay[7] found a "reasonably high degree of correspondence" in responses to several items which were included in the survey reported in *Science Indicators—1972.* Similar attitudes, for example, were found in both surveys regarding the confidence and prestige associated with scientists and engineers, the desired extent of social control of science and technology, and ratings of benefits in different areas, such as health and space exploration. The LaPorte and Metlay survey, in addition, found that attitudes toward science differ from those toward technology; "there was considerable agreement that scientific activities are intrinsically beneficial and should not be controlled", whereas "the public reaction to the impact of technology upon society is one of wariness and some skepticism".

[4] *Ibid.*

[5] The institutions for which data were available over the three years included medicine, science, education, the military, Supreme Court, Federal executive branch, Congress, major U.S. companies, the press, television, and labor.

[6] *Codebook of the General Social Survey,* National Opinion Research Center, 1973 and 1974.

[7] Todd LaPorte and Daniel Metlay, "Technology Observed: Attitudes of a Wary Public," *Science,* Vol. 188 (1975), pp. 121-127.

Appendix

Table 1-1. R&D expenditures as a percent of Gross National Product (GNP), by country, 1961-74

Country	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974 (est.)
	R&D expenditures as a percent of Gross National Product													
United States	2.75	2.75	2.90	2.99	2.93	2.92	2.92	2.86	2.76	2.66	2.53	2.45	2.35	2.29
France	1.38	1.43	1.53	1.78	1.99	2.07	2.16	2.11	1.96	1.88	1.87	1.82	1.73	NA
West Germany	1.08	1.23	1.38	1.54	1.70	1.78	1.94	1.93	1.99	2.12	2.29	2.37	2.36	2.41
United Kingdom	2.69	NA	NA	2.62	NA	2.79	2.75	2.70	2.73	NA	NA	NA	NA	NA
Japan	NA	NA	1.25	NA	NA	NA	1.34	NA	1.50	NA	1.65	1.89	1.92	NA
U.S.S.R.	NA	2.18	2.37	2.42	2.40	2.42	2.55	NA	2.82	2.73	2.79	3.04	3.10	3.06
	R&D expenditures (national currency in billions)													
United States[1]	14.3	15.4	17.1	18.9	20.1	21.9	23.2	24.7	25.7	26.0	26.7	28.4	30.4	32.0
France[2]	4.4	5.2	6.3	8.1	9.8	11.0	12.4	13.3	14.2	15.2	16.8	18.3	19.8	NA
West Germany[2]	3.6	4.4	5.3	6.5	7.8	8.7	9.6	10.4	12.1	14.5	17.4	19.8	22.0	24.0
United Kingdom[2]	.6	NA	NA	.8	NA	.9	1.0	1.0	1.1	NA	NA	NA	NA	NA
Japan[2]	NA	NA	321.1	NA	NA	NA	606.3	NA	933.2	NA	1,345.9	1,791.9	2,215.8	NA
U.S.S.R.[1]	3.8	4.3	4.9	5.4	5.8	6.3	7.2	7.9	9.3	9.9	11.0	12.2	13.3	13.9
	Gross National Product (national currency in billions)													
United States	520.1	560.3	590.5	632.4	684.9	749.9	793.9	864.2	930.3	977.1	1,054.9	1,158.0	1,294.9	1,396.7
France	320.0	367.2	412.0	456.7	490.0	532.0	574.0	629.0	723.0	808.0	899.0	1,007.6	1,145.6	NA
West Germany	332.6	360.1	384.0	420.9	460.4	490.7	495.5	540.0	605.2	685.6	761.9	834.6	930.3	995.0
United Kingdom	24.4	NA	NA	29.5	NA	33.2	35.0	37.7	39.7	NA	NA	NA	NA	NA
Japan	NA	NA	25,592.1	NA	NA	NA	45,296.7	NA	62,259.9	NA	81,577.0	94,726.5	115,263.1	NA
U.S.S.R.	NA	197.2	206.8	223.2	242.1	260.1	282.0	NA	329.6	362.6	394.8	401.8	429.4	453.7

[1] Expenditures for performance of R&D.
[2] Expenditures for performance of R&D plus associated capital expenditures.

SOURCES: Organisation for Economic Co-operation and Development, *International Survey of the Resources Devoted to R&D by OECD Member Countries* for 1963, 1967, 1969, and 1971.

France: Delegation Generale a la Recherche Scientifique et Technique, unpublished statistics.
Japan: Scientific Counselor, Embassy of Japan, Washington, D.C.
United Kingdom: Science and Technology Department, The British Embassy, Washington, D.C.
West Germany: Statistisches Bundesamt, unpublished statistics.
U.S.S.R.: Dr. Robert Campbell, Department of Economics, Indiana University.

Table 1-2. Scientists and engineers[1] engaged in R&D, by country, 1963-73

Country	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
	Scientists and engineers[1] engaged in R&D per 10,000 population										
United States	NA	24.7	25.4	NA	NA	27.4	27.5	26.8	25.6	25.0	24.9
U.S.S.R.	18.8	20.3	21.6	25.2	25.8	27.3	29.1	30.7	32.6	34.3	37.2
Japan	12.0	NA	NA	NA	15.8	NA	16.9	NA	18.9	NA	NA
West Germany	NA	5.7	NA	NA	10.3	NA	12.5	NA	14.9	16.2	17.8
France	6.7	NA	NA	NA	9.9	NA	10.9	NA	11.1	NA	NA
	Scientists and engineers engaged in R&D (in thousands)										
United States	NA	474.5	494.1	NA	NA	550.4	558.2	549.5	529.7	521.5	523.1
U.S.S.R.	422.8	463.2	499.4	558.4	605.6	651.5	698.9	746.2	797.8	848.8	931.0
Japan	114.8	NA	NA	NA	157.6	NA	172.0	NA	198.1	NA	NA
West Germany	NA	33.4	NA	NA	61.6	NA	76.3	NA	90.0	100.0	110.0
France	32.2	NA	NA	NA	49.2	NA	54.7	NA	56.7	NA	NA
	Population (in thousands)										
United States	189,242	191,889	194,303	196,560	198,712	200,706	202,677	204,875	207,045	208,842	210,396
U.S.S.R.	225,060	228,150	230,940	233,530	235,990	238,320	240,550	242,760	245,090	247,460	250,000
Japan	95,900	96,900	97,950	98,850	99,870	101,000	102,200	103,390	104,650	105,990	108,710
West Germany	57,610	58,290	59,040	59,680	59,870	60,170	60,840	60,650	61,290	61,690	61,970
France	47,820	48,310	48,760	49,160	49,550	49,910	50,320	50,770	51,250	51,700	51,915

[1] Includes all scientists and engineers (full-time equivalent basis). Data for the United Kingdom are not available.

SOURCE: Organisation for Economic Co-operation and Development, *International Survey of Resources Devoted to R&D by OECD Member Countries,* for 1963, 1964, 1967, 1969, and 1971; United Nations, *Demographic Yearbook, 1972* and UN estimates for 1973; U.S.S.R. estimates by Robert W. Campbell, Department of Economics, Indiana University.

Table 1-3. Distribution of government R&D expenditures among areas by country, 1961-73

National objectives	National currency in millions			Percent distribution		
United States	1961-62	1966-67	1971-72	1961-62	1966-67	1971-72
National defense	7,338.5	8,264.8	8,584.7	70.7	49.0	52.6
Space	1,225.9	5,307.0	2,957.6	11.8	31.5	18.1
Nuclear energy	755.0	875.0	838.0	7.3	5.2	5.1
Economic development	339.1	792.3	1,322.1	3.3	4.7	8.1
Health	500.6	968.8	1,379.8	4.8	5.7	8.5
Community services	99.9	321.1	729.2	1.0	1.9	4.5
Advancement of science	118.2	308.6	465.4	1.1	1.8	2.9
United Kingdom	1961-62	1966-67	1972-73	1961-62	1966-67	1972-73
National defense	248.6	260.4	335.0	64.8	52.3	44.0
Space	2.7	21.4	11.9	0.7	4.3	1.6
Nuclear energy	56.5	65.2	67.3	14.7	13.1	8.8
Economic development	37.9	71.0	177.6	9.9	14.3	23.3
Health	5.7	13.0	32.8	1.5	2.6	4.3
Community services	0.7	1.3	4.5	0.2	0.3	0.6
Advancement of science	26.0	57.8	119.9	6.8	11.6	15.8
France	1961	1967	1972	1961	1967	1972
National defense	1,310.0	3,082.0	3,050.0	44.2	34.9	27.8
Space	16.5	522.8	730.0	0.6	5.9	6.7
Nuclear energy	735.0	1,723.2	1,600.0	24.8	19.5	14.6
Economic development	231.6	1,381.0	2,200.0	7.8	15.6	20.1
Health	13.0	116.1	200.0	0.4	1.3	1.8
Community services	12.7	81.0	170.0	0.4	0.9	1.6
Advancement of science	592.3	1,758.1	2,800.0	20.0	19.9	25.5
West Germany	1961	1966	1971	1961	1966	1971
National defense	381.0	803.0	1,180.0	22.3	19.0	15.0
Space	NA	177.0	522.0	NA	4.2	6.6
Nuclear energy	267.0	693.0	1,230.0	15.6	16.4	15.6
Economic development	NA	NA	1,057.0	NA	NA	13.4
Health	NA	NA	195.0	NA	NA	2.5
Community services	NA	NA	133.0	NA	NA	1.7
Advancement of science	639.0	1,488.0	3,190.0	37.4	35.3	40.6
Japan	1961-62	1965-66	1969-70	1961-62	1965-66	1969-70
National defense	3,162.0	4,495.0	6,523.0	3.7	2.7	2.2
Space	NA	141.0	2,083.0	NA	0.1	0.7
Nuclear energy	5,881.0	4,944.0	22,539.0	7.0	3.0	7.5
Economic development	25,446.0	44,898.0	69,987.0	30.1	27.2	23.2
Health	724.0	3,679.0	5,492.0	0.9	2.2	1.8
Community services	1,071.0	2,818.0	7,254.0	1.3	1.7	2.4
Advancement of science	47,321.0	103,163.0	185,376.0	55.9	62.5	61.4

SOURCE: Organisation for Economic Co-operation and Development, *Changing Priorities for Government R&D*, July, 1973.

Table 1-4. Percent of the scientific literature[1] citing countries other than the author's own country, by selected fields,[2] 1973

Fields	Total citations from the 6 major countries	Citations to countries other than the author's country	Citations to the author's country	Percent foreign citations
Chemistry	338,993	233,176	105,817	69
Physics	270,090	170,985	99,105	63
Biology and biomedical research	440,215	246,471	193,744	56
Engineering	80,654	43,523	37,131	54
Clinical medicine	604,858	320,158	284,700	53
Mathematics	25,759	13,355	12,404	52
Earth & space sciences	73,248	35,384	37,864	48
Psychology	42,298	11,934	30,364	28
Eight field total	1,876,115	1,074,986	801,129	57

[1] Based on 2,121 of the journals in the *Science Citation Index* for 1973. Included is the literature of the first six countries ranked by the number of their scientific publications: United States, United Kingdom, West Germany, France, U.S.S.R. and Japan.
[2] See Appendix table 1-7a for the description of fields and subfields. The social sciences are excluded because comparable data are not available.

SOURCE: Computer Horizons, Inc., *Indicators of the Quantity and Quality of the Scientific Literature*, 1975 (A study commissioned specifically for this report).

Table 1-5. Participation in international scientific congresses, by the United States and other countries, 1960-74

Year	Total participants	U.S. participants	Non-U.S. participants
1960-62	33,082	9,033	24,049
1963-65	37,964	10,012	27,952
1966-68	59,748	12,297	47,451
1969-71	55,711	12,956	42,755
1972-74	73,819	18,630	55,189

SOURCE: National Academy of Sciences, special tabulations.

Table 1-6. Scientific literature[1] in selected fields[2] as a percent of total literature, by country, 1965-73

Selected field and year	Total literature (number)	Percent of total						
		United States	United Kingdom	West Germany[3]	France	U.S.S.R.	Japan	Other countries
Chemistry								
1965	34,657	25.9	7.7	8.2	3.9	30.9	4.1	19.3
1967	39,730	24.5	7.9	8.4	5.9	28.8	5.3	19.2
1969	43,362	24.2	8.2	7.9	5.7	28.5	6.4	19.2
1971	45,052	23.9	8.4	6.8	6.2	29.0	5.9	19.8
1972	45,665	22.4	7.0	5.4	6.0	30.1	6.0	23.2
1973	45,778	21.2	6.4	5.4	5.8	32.4	6.3	22.6
Engineering								
1965	10,006	49.9	11.2	4.7	1.4	12.6	2.4	17.8
1967	11,968	48.8	11.3	5.6	1.8	12.5	2.8	17.2
1969	13,222	48.3	11.0	6.2	1.8	12.5	2.9	17.4
1971	13,765	49.7	9.0	6.1	2.2	11.8	3.9	17.3
1972	11,992	44.6	9.7	6.4	2.4	11.4	3.9	21.7
1973	12,690	43.7	10.9	7.0	2.5	9.4	4.5	21.9
Mathematics								
1965	[4]2,971	23.9	6.6	6.3	5.6	22.4	4.2	31.8
1967	4,298	23.9	4.6	6.4	4.5	26.4	4.7	29.8
1969	3,024	26.9	6.4	6.0	6.9	20.0	5.2	27.1
1971	3,739	27.8	3.9	6.5	6.0	22.2	7.0	26.7
1972	3,599	29.3	3.9	6.8	5.6	28.6	5.0	20.8
1973	4,844	23.6	4.4	7.0	5.5	30.3	4.2	25.1
Molecular biology								
1965	24,321	46.6	9.5	4.8	9.4	3.0	4.2	22.4
1967	25,858	48.6	11.0	5.4	7.4	2.1	4.8	20.7
1969	29,359	47.6	9.3	5.5	9.0	1.8	4.9	21.8
1971	30,148	48.7	8.9	5.1	8.9	1.8	5.0	21.6
1972	31,032	45.9	9.7	4.4	9.6	1.8	5.4	23.3
1973	33,619	46.7	9.4	4.3	8.0	1.9	5.9	23.9
Physics								
1965	23,224	41.3	8.2	7.4	4.8	15.7	4.4	18.2
1967	27,121	42.1	8.6	7.5	5.3	13.8	5.2	17.5
1969	29,353	41.0	8.3	7.2	5.4	14.6	5.1	18.4
1971	29,824	42.4	8.1	5.8	5.1	13.8	6.0	18.7
1972	31,031	38.5	7.7	5.2	6.1	15.1	5.6	21.7
1973	31,548	38.4	7.2	5.7	5.7	14.4	6.5	22.0
Psychology								
1965	3,537	79.3	8.1	0.5	0.2	—	0.5	11.4
1967	3,967	79.2	6.4	0.5	0.2	—	0.6	13.2
1969	4,308	76.6	7.8	1.6	0.1	0.1	0.4	13.5
1971	4,075	76.5	7.9	0.8	0.2	—	0.5	14.1
1972	4,091	74.4	8.5	0.7	0.2	0.2	0.9	14.9
1973	4,443	74.4	8.1	0.6	0.6	—	0.8	15.5
Systematic biology								
1967	[4]6,201	35.8	6.1	4.1	4.4	8.3	3.5	37.8
1969	6,101	29.4	6.0	4.9	4.8	9.0	5.0	41.0
1971	7,050	33.3	7.2	5.3	5.2	6.4	4.3	38.2
1972	5,192	31.2	6.5	4.4	5.5	2.5	5.0	44.9
1973	3,342	30.8	6.5	5.1	5.3	10.4	4.6	37.4

[1] Includes articles, letters and notes from the sample of 492 scientific journals most heavily cited in 1965.
[2] The social sciences are excluded because comparable data are not available.
[3] Prior to 1972, data for East Germany were included in the fields of chemistry, engineering, molecular biology, physics, and psychology.
[4] For mathematics and systematic biology, these numbers are the size of the literature *sample* from which the percent distributions were derived, and should not be used as counts of articles.

NOTE: Percents may not add to 100 because of rounding.

SOURCE: Computer Horizons, Inc., *Indicators of the Quantity and Quality of the Scientific Literature*, 1975 (A study commissioned specifically for this report).

Table 1-7. Percent distribution of scientific literature[1] by selected field,[2] for each country, 1973

Fields	United States	United Kingdom	West Germany	France	U.S.S.R.	Japan	Other countries	World total
	Percent in each field							
All fields	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Clinical medicine	29.9	31.1	31.9	28.7	9.9	18.5	28.5	27.3
Biology and biomedical research	24.9	23.8	20.1	25.0	12.4	20.4	25.1	23.2
Chemistry	9.8	13.9	16.9	20.0	33.1	29.6	18.7	16.5
Physics	10.8	11.1	11.9	12.8	25.5	16.4	11.7	12.8
Earth and space sciences	5.1	3.8	2.3	3.8	4.7	1.7	3.9	4.2
Engineering	10.8	12.0	13.2	5.3	13.4	10.8	7.8	10.2
Psychology	5.1	1.8	0.4	0.5	0.1	0.3	1.5	2.6
Mathematics	3.8	2.5	3.5	4.0	0.9	2.4	2.9	3.1
	Total number of publications							
Total count of literature	109,320	25,462	16,461	15,184	24,435	14,309	73,723	278,894
Percent distribution	39.2	9.1	5.9	5.4	8.8	5.1	26.4	100.0

[1] Includes 278,894 articles, letters and notes from a sample of 2,121 scientific journals. Because of the way in which this sample of journals was chosen, these profiles may understate certain fields; e.g., Russian mathematics articles may be understated here.

[2] See Appendix table 1-7a for the description of fields and subfields. The social sciences are excluded because comparable data are not available.

NOTE: Percents may not add to 100 because of rounding.

SOURCE: Computer Horizons, Inc., *Indicators of the Quantity and Quality of the Scientific Literature*, 1975 (A study commissioned specifically for this report).

Table 1-7a. Fields and subfields of scientific literature, 1973

- Clinical medicine
  - General and internal medicine
  - Allergy
  - Anesthesiology
  - Cancer
  - Cardiovascular system
  - Dentistry
  - Dermatology & venereal diseases
  - Endocrinology
  - Fertility
  - Gastroenterology
  - Geriatrics
  - Hematology
  - Immunology
  - Obstetrics & gynecology
  - Neurology & neurosurgery
  - Ophthalmology
  - Orthopedics
  - Arthritis & rheumatism
  - Otorhinolaryngology
  - Pathology
  - Pediatrics
  - Pharmacology
  - Pharmacy
  - Psychiatry
  - Radiology & nuclear medicine
  - Respiratory system
  - Surgery
  - Tropical medicine
  - Urology
  - Nephrology
  - Veterinary medicine
  - Addictive diseases
  - Hygiene & public health
  - Miscellaneous clinical medicine
- Biology and biomedical research
  - Biomedical research
    - Physiology
    - Anatomy & morphology
    - Embryology
    - Genetics & heredity
    - Nutrition & dietetics
    - Biochemistry & molecular biology
    - Biophysics
    - Cell biology cytology & histology
    - Microbiology
    - Virology
    - Parasitology
    - Biomedical engineering
    - Microscopy
    - Miscellaneous biomedical research
    - General biomedical research
  - Biology
    - General biology
    - General zoology
    - Entomology
    - Miscellaneous zoology
    - Marine biology & hydrobiology
    - Botany
    - Ecology
    - Agriculture & food science
    - Dairy & animal science
    - Miscellaneous biology
- Chemistry
  - Analytical chemistry
  - Organic chemistry
  - Inorganic & nuclear chemistry
  - Applied chemistry
  - General chemistry
  - Polymers
  - Physical chemistry
- Physics
  - Chemical physics
  - Solid state physics
  - Fluids & plasmas
  - Applied physics
  - Acoustics
  - Optics
  - General physics
  - Nuclear & particle physics
  - Miscellaneous physics
- Earth and space science
  - Astronomy & astrophysics
  - Meteorology and atmospheric science
  - Geology
  - Earth & planetary science
  - Geography
  - Oceanography & limnology
- Engineering and technology
  - Chemical engineering
  - Mechanical engineering
  - Civil engineering
  - Electrical engineering & electronics
  - Miscellaneous engineering & technology
  - Industrial engineering
  - General engineering
  - Metals & metallurgy
  - Materials science
  - Nuclear technology
  - Aerospace technology
  - Computers
  - Library & information science
  - Operations research & management science
- Psychology
  - Clinical psychology
  - Personality & social psychology
  - Developmental & child psychology
  - Experimental psychology
  - General psychology
  - Miscellaneous psychology
  - Behavioral science
- Mathematics
  - Algebra
  - Analysis & functional analysis
  - Geometry
  - Logic
  - Number theory
  - Probability
  - Statistics
  - Topology
  - Computing theory & practice
  - Applied mathematics
  - Combinatorics & finite mathematics
  - Physical mathematics
  - General mathematics
  - Miscellaneous mathematics

Table 1-7b. Citation indices of scientific literature[1] in selected fields,[2] by selected countries, 1973

Cited country	Citing country	Clinical medicine	Biology and biomedical research	Chemistry	Physics	Earth and space science	Engi-neering	Psy-chology	Mathe-matics
		Field of science							
United States	United States	1.52	1.45	1.97	1.60	1.42	1.49	1.05	1.25
	World	1.31	1.29	1.54	1.38	1.31	1.07	1.03	1.17
	Non-U.S.	1.15	1.15	1.38	1.26	1.18	0.90	0.97	1.07
United Kingdom	United Kingdom ...	2.26	1.91	2.11	1.37	1.59	1.75	1.87	1.80
	World	1.26	1.17	1.40	0.93	0.97	1.04	0.93	1.08
	Non-U.K.	1.13	1.09	1.30	0.87	0.92	0.86	0.86	0.99
West Germany	West Germany	2.31	1.82	3.62	1.54	1.72	4.03	(3)	1.85
	World	0.55	0.79	1.46	1.03	0.71	0.87	(3)	0.91
	Non-W. Germany ..	0.41	0.73	1.29	1.00	0.68	0.58	(3)	0.83
France[4]	France	2.62	2.10	2.14	1.14	1.56	10.37	(3)	2.24
	World	0.50	0.64	0.66	0.80	0.57	1.08	(3)	0.77
	Non-France	0.36	0.58	0.56	0.78	0.53	0.67	(3)	0.73
U.S.S.R.	U.S.S.R.	9.44	4.78	2.54	2.51	3.14	6.18	(3)	13.25
	World	0.18	0.29	0.42	0.61	0.35	1.02	(3)	0.53
	Non-U.S.S.R.	0.05	0.14	0.16	0.32	0.21	0.12	(3)	0.31
Japan	Japan	4.66	3.62	1.48	2.14	3.75	3.58	(3)	3.61
	World	0.57	0.82	0.69	0.75	0.73	0.76	(3)	0.65

[1] Based on 278,894 articles, letters and notes in a sample of 2,121 journals.
[2] See Appendix table 1-7a for a description of the fields. The social sciences are excluded because comparable data are not available.
[3] Because these countries had less than 2 percent of the world's literature total in psychology, reliable citation ratios cannot be calculated.
[4] Although French scientific journals may have severe space restrictions which discourage complete citations, the articles themselves tend to be more specific, covering less substantive material. For this reason, there may be an inflation of French publications in the scientific literature, making them more subject to citation than their significance warrants.

SOURCE: Computer Horizons, Inc., *Indicators of the Quantity and Quality of the Scientific Literature*, 1975 (A study commissioned specifically for this report).

Table 1-8. Nobel Prizes awarded in science, for selected countries, 1901-74

Date	United States	United Kingdom	Germany[1]	France	U.S.S.R.
	Number of Nobel Prizes per 10 million population				
1901-1910	0.12	1.24	2.80	1.47	0.15
1911-1920	0.20	0.71	2.00	1.01	—
1921-1930	0.26	1.56	2.21	0.75	—
1931-1940	0.70	1.49	2.05	0.49	—
1941-1950	0.98	1.42	0.91	—	—
1951-1960	1.74	1.75	0.59	—	0.20
1961-1970	1.35	2.23	0.91	1.05	0.13
1971-1974	0.63	1.08	0.17	—	—
	Number of Nobel Prizes awarded				
1901-1910	1	5	12	6	2
1911-1920	2	3	7	4	—
1921-1930	3	7	8	3	—
1931-1940	9	7	8	2	—
1941-1950	14	7	4	—	—
1951-1960	29	9	3	—	4
1961-1970	26	12	5	5	3
1971-1974	13	6	1	—	—
Total	97	56	48	20	9
	Population (In millions)				
1901-1910	84.25	40.31	42.81	40.79	133.06
1911-1920	99.44	42.58	35.00	39.43	147.89
1921-1930	114.77	44.79	36.25	39.95	167.15
1931-1940	127.84	47.05	39.05	41.23	187.00
1941-1950	142.43	49.42	44.22	41.52	187.50
1951-1960	166.47	51.56	50.54	43.71	197.20
1961-1970	192.77	53.80	54.91	47.59	230.05
1971-1974	207.64	55.52	59.29	50.71	247.85

[1] Before 1946, includes East Germany.

SOURCE: The Nobel Foundation, *Les Prix Nobel*, annual series.

Table 1-9. Nobel Prizes awarded by field for selected countries, 1901-1974

Date	Total	United States	France	Germany[1]	U.S.S.R.	United Kingdom	Other
	Number of prizes in physics						
1901-1910	14	1	4	3	—	2	4
1911-1920	10	—	—	4	—	3	3
1921-1930	12	2	2	3	—	2	3
1931-1940	10	3	—	1	—	3	3
1941-1950	8	2	—	1	—	3	2
1951-1960	20	12	—	1	3	2	2
1961-1970	18	9	2	2	3	—	2
1971-1974	9	5	—	—	—	4	—
Total	101	34	8	15	6	19	19
	Number of prizes in chemistry						
1901-1910	10	—	1	5	—	2	2
1911-1920	8	1	3	3	—	—	1
1921-1930	10	—	—	4	—	3	3
1931-1940	12	2	2	4	—	1	3
1941-1950	11	4	—	3	—	1	3
1951-1960	13	5	—	1	1	5	1
1961-1970	15	4	—	2	—	6	3
1971-1974	7	4	—	1	—	1	1
Total	86	20	6	23	1	19	17
	Number of prizes in physiology/medicine						
1901-1910	12	—	1	4	2	1	4
1911-1920	6	1	1	—	—	—	4
1921-1930	11	1	1	1	—	2	6
1931-1940	13	4	—	3	—	3	3
1941-1950	17	8	—	—	—	3	6
1951-1960	19	12	—	1	—	2	4
1961-1970	26	13	3	1	—	6	3
1971-1974	9	4	—	—	—	1	4
Total	113	43	6	10	2	18	34

[1] Before 1946, includes East Germany.

SOURCE: The Nobel Foundation, *Les Prix Nobel*, annual series.

Table 1-10. Patents granted to U.S. nationals by foreign countries[1] and to foreign nationals[1] by the United States, 1966-73

Patents granted	1966	1967	1968	1969	1970	1971	1972	1973
U. S. balance	36,066	34,441	36,045	35,887	33,697	31,445	30,520	25,306
Patents granted to U.S. nationals by foreign countries	45,633	44,350	45,168	47,825	45,918	47,311	47,359	41,186
Patents granted to foreign nationals by the United States	9,567	9,909	9,123	11,938	12,221	15,866	16,839	15,880

[1] Including Canada, West Germany, Japan, United Kingdom, U.S.S.R., Belgium, Denmark, Ireland, Luxembourg, and the Netherlands.

SOURCE: World Intellectual Property Organization, *Industrial Property,* Geneva: 1966-73 (December issues).

Table 1-11. U.S. patent balance with selected countries, 1966-73

Selected country	1966	1967	1968	1969	1970	1971	1972	1973
Canada:								
Balance	15,676	16,592	16,686	18,153	17,598	16,665	16,045	11,619
Granted to U.S.	16,614	17,583	17,583	19,147	18,663	17,992	17,289	12,964
Granted by U.S.	938	991	897	994	1,065	1,327	1,244	1,345
West Germany:								
Balance	-248	-360	362	-40	-1,552	-1,128	-1,153	-639
Granted to U.S.	3,733	3,406	3,804	4,483	2,882	4,393	4,575	4,949
Granted by U.S.	3,981	3,766	3,442	4,523	4,434	5,521	5,728	5,588
Japan:								
Balance	3,561	2,008	3,439	2,505	2,149	1,667	794	546
Granted to U.S.	4,683	3,432	4,903	4,657	4,774	5,700	5,948	5,485
Granted by U.S.	1,122	1,424	1,464	2,152	2,625	4,033	5,154	4,939
United Kingdom:								
Balance	11,440	10,877	10,107	9,503	9,776	9,226	9,837	8,866
Granted to U.S.	14,117	13,676	12,588	12,678	12,728	12,682	13,001	11,717
Granted by U.S.	2,677	2,799	2,481	3,175	2,952	3,456	3,164	2,851
Other E.E.C. countries[1]								
Balance	5,700	5,439	5,481	5,842	5,743	5,143	5,093	4,914
Granted to U.S.	6,483	6,253	6,225	6,777	6,670	6,346	6,287	6,071
Granted by U.S.	783	814	744	935	927	1,203	1,194	1,157
U.S.S.R.:								
Balance	-63	-115	-30	-76	-17	-128	-96	-177
Granted to U.S.	3	0	65	83	201	198	259	205
Granted by U.S.	66	115	95	159	218	326	355	382

[1] Other European Economic Community (E.E.C.) countries include Belgium, Denmark, Ireland, Luxembourg, and the Netherlands. Data from France are not reliable for use in this indicator.

SOURCE: World Intellectual Property Organization, *Industrial Property,* Geneva: 1966-73 (December Issues).

Table 1-12. Major technological innovations, by selected countries, 1953-73

Period	United States	United Kingdom	West Germany	Japan	France	Total
	Percentage of total					
1953-55	75	14	6	0	5	100
1956-58	82	9	5	0	5	100
1959-61	68	21	2	2	7	100
1962-64	66	17	5	12	0	100
1965-67	55	23	12	8	3	100
1968-70	57	19	8	13	4	100
1971-73	58	16	9	10	8	100
	Number of innovations					
1953-55	63	12	5	0	4	84
1956-58	36	4	2	0	2	44
1959-61	38	12	1	1	4	56
1962-64	55	14	4	10	0	83
1965-67	36	15	8	5	2	66
1968-70	45	15	6	10	3	79
1971-73	46	13	7	8	6	80

NOTE: Detail may not add to totals because of rounding.

SOURCE: Gellman Research Associates, Inc., *Indicators of International Trends in Technological Innovation*, 1975 (A study commissioned specifically for this report).

Table 1-13. Mean time in years between invention and innovation, for selected countries, 1953-73[1]

Period	United States	Japan	West Germany	France	United Kingdom
1953-62	8.4	([2])	5.5	7.5	5.1
1963-73	6.4	3.6	5.6	7.3	7.5

[1] Refers to the date of the innovation.
[2] Sample size does not allow calculation of the time interval.

SOURCE: Gellman Research Associates, Inc., *Indicators of International Trends in Technological Innovation*, 1975 (A study commissioned specifically for this report).

Table 1-14. "Radicalness" of innovations by selected countries, 1953-73

Country	Improvement of existing technology	Major technological advance	Radical breakthrough
	Percentage of each country's innovations		
United States	41	31	27
United Kingdom	4	40	56
France	12	65	24
West Germany	36	50	14
Japan	38	54	8
	Number of innovations		
United States	98	74	65
United Kingdom	2	18	25
France	2	11	4
West Germany	8	11	3
Japan	10	14	2

NOTE: Detail may not add to 100 percent because of rounding.

SOURCE: Gellman Research Associates, Inc., *Indicators of International Trends in Technological Innovation*, 1975 (A study commissioned specifically for this report).

Table 1-15. U.S. receipts and payments for patents, manufacturing rights, licenses, etc., by country, 1960-74[1]
[Dollars in millions]

Year	Total	Western Europe	Japan	Developing nations	Other
1960					
Balance	$210	$105	$48	$25	$31
Receipts	248	140	48	26	33
Payments	38	35	0	1	2
1961					
Balance	201	94	50	25	32
Receipts	244	132	52	26	34
Payments	43	38	2	1	2
1962					
Balance	212	95	51	29	38
Receipts	256	133	53	30	40
Payments	44	38	2	1	2
1963					
Balance	222	98	57	30	37
Receipts	273	144	58	31	39
Payments	51	46	1	1	2
1964					
Balance	241	106	65	33	35
Receipts	301	162	66	34	38
Payments	60	56	1	1	3
1965					
Balance	268	128	65	35	40
Receipts	335	189	66	37	43
Payments	67	61	1	2	3
1966					
Balance	277	119	67	46	46
Receipts	353	186	70	50	48
Payments	76	67	3	4	2
1967					
Balance	289	97	91	48	54
Receipts	393	190	95	51	57
Payments	104	93	4	3	3
1968					
Balance	331	102	126	59	45
Receipts	437	196	130	63	49
Payments	106	94	4	4	4
1969					
Balance	366	115	151	56	44
Receipts	486	222	155	61	49
Payments	120	107	4	5	5
1970					
Balance	459	148	198	61	52
Receipts	573	247	202	68	56
Payments	114	99	4	7	4
1971					
Balance	495	158	219	67	51
Receipts	618	268	223	71	56
Payments	123	110	4	4	5
1972					
Balance	516	150	234	74	58
Receipts	655	270	240	80	65
Payments	139	120	6	6	7
1973					
Balance	549	160	261	71	58
Receipts	725	306	274	81	65
Payments	176	146	13	10	7
1974 (preliminary)					
Balance	601	200	241	91	69
Receipts	781	348	249	107	77
Payments	180	148	8	16	8

[1] Represents U.S. receipts and payments arising out of agreements by U.S. residents with residents or governments of foreign countries to sell or buy outright or provide or be provided with the use of intangible assets or rights such as patents, techniques, processes, formulae, designs, trademarks, copyrights, franchises, manufacturing rights, and other similar intangible property or rights. Excludes fees and royalties connected with U.S. and foreign direct investments and excludes film rentals.

NOTE: Detail may not add to totals because of rounding.

SOURCE: Department of Commerce, Bureau of Economic Analysis, *Survey of Current Business*, June 1975.

Table 1-16. Real Gross Domestic Product per employed civilian, for selected countries compared with the United States, 1960-74 (Indexes, United States = 100)

Year	United States	France	West Germany	Japan	United Kingdom
1960	100	55.1	52.0	24.4	50.7
1965	100	60.2	55.7	31.7	48.6
1967	100	62.9	56.4	36.3	49.3
1970	100	71.4	67.0	48.7	52.6
1971	100	72.9	67.0	50.4	53.5
1972	100	74.1	67.6	53.3	53.3
1973	100	75.7	69.2	55.9	53.4
1974	100	81.1	73.8	57.4	55.6

SOURCE: U.S. Department of Labor, Bureau of Labor Statistics, Office of Productivity and Technology, *Comparative Real Gross Domestic Product, Real GDP per Capita, and Real GDP per Employed Civilian for Six Countries*, July 1975.

Table 1-17. Productivity[1] in manufacturing industries, by selected countries, 1960-74 (Index, 1960 = 100)

Year	United States	Japan	France	West Germany	United Kingdom
1960	100.0	100.0	100.0	100.0	100.0
1961	102.5	113.1	104.7	105.4	100.8
1962	108.3	118.1	109.5	112.2	103.3
1963	112.7	127.6	116.0	118.1	108.9
1964	118.0	144.6	121.8	127.3	116.8
1965	122.7	150.7	128.8	136.1	120.3
1966	124.3	165.9	137.8	141.6	124.6
1967	124.2	190.5	145.6	150.6	130.2
1968	130.2	214.5	162.2	162.0	138.9
1969	133.3	247.6	168.0	171.4	140.8
1970	134.0	279.0	176.4	175.8	142.1
1971	143.1	289.0	185.6	184.2	148.7
1972	151.2	312.2	198.1	195.9	154.8
1973	159.4	368.8	209.6	209.9	165.6
1974 (est.)	160.5	380.8	221.1	215.1	165.8

[1] Output per man-hour.

SOURCE: P. Capdevielle and A. Neef, "Productivity and Unit Labor Costs in the United States and Abroad", *Monthly Labor Review*, July 1975.

Table 1-18. Unit labor cost[1] in manufacturing industries, by selected countries, 1960-74 (Index, 1960 = 100)

Year	United States	Japan	France	West Germany	United Kingdom
1960	100.0	100.0	100.0	100.0	100.0
1961	100.6	102.8	105.2	105.9	106.9
1962	99.1	112.5	110.7	112.6	109.8
1963	98.4	116.3	115.5	114.2	108.9
1964	98.2	115.3	118.2	114.2	108.8
1965	97.0	124.7	120.4	117.3	115.6
1966	100.0	124.8	119.6	123.0	121.0
1967	105.0	121.8	122.7	122.4	119.0
1968	107.5	125.7	124.9	120.6	119.5
1969	111.7	128.9	127.5	124.2	127.4
1970	118.9	135.8	136.1	139.5	144.9
1971	118.9	151.8	144.8	151.7	158.0
1972	118.8	162.6	151.7	159.2	171.5
1973	120.6	171.3	162.8	168.7	181.7
1974 (est.)	131.2	220.1	180.7	187.5	216.9

[1] In national currency unadjusted for inflation.

SOURCE: P. Capdevielle and A. Neef, "Productivity and Unit Labor Costs in the United States and Abroad", *Monthly Labor Review,* July 1975.

Table 1-19. U.S. trade balance in R&D-intensive and non-R&D-intensive manufactured products, 1960-74 (Dollars in millions)

	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
R&D-intensive															
Balance	5,891	6,237	6,720	6,958	7,970	8,177	8,020	8,817	9,755	10,471	11,722	11,727	11,012	15,101	23,612
Export	7,597	8.018	8,715	8,975	10,267	11,107	12,203	13,407	15,312	16,955	19,274	20,228	22,003	29,088	41,115
Import	1,706	1,781	1,995	2,017	2,297	2,930	4,183	4,590	5,537	6,484	7,552	8,501	10,991	13,987	17,503
Non R&D-intensive															
Balance	-179	-12	-691	-765	-678	-2,027	-3,325	-3,729	-6,581	-6,698	-8,285	-11,698	-15,039	-15,370	-16,296
Export	4,962	4,730	4,940	5,284	6,121	6,281	6,913	7,437	8,506	9,830	10,069	10,215	11,737	15,643	22,412
Import	5,141	4,742	5,631	6,049	6,799	8,308	10,238	11,166	15,087	16,528	18,354	21,913	26,776	31,013	38,708

SOURCE: U.S. Department of Commerce, Domestic and International Business Administration, *Overseas Business Reports,* April 1975 and April 1972.

Table 1-20. U.S. trade balance in R&D-intensive manufactured products, by product group, 1960-74
(Dollars in millions)

Product	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Chemicals															
Balance	955	1,051	1,104	1,294	1,662	1,633	1,719	1,844	2,158	2,155	2,376	2,224	2,118	3,286	4,831
Export	1,776	1,789	1,876	2,009	2,364	2,402	2,676	2,802	3,287	3,383	3,826	3,836	4,133	5,749	8,822
Import	821	738	772	715	702	769	957	958	1,129	1,228	1,450	1,612	2,015	2,463	3,991
Machinery, nonelectrical															
Balance	2,948	3,288	3,547	3,574	3,989	4,114	4,102	4,218	4,280	4,838	5,583	5,268	5,325	6,904	10,633
Export	3,386	3,743	4,087	4,209	4,860	5,274	5,779	6,181	6,560	7,460	8,686	8,772	9,864	12,556	17,299
Import	438	455	540	635	871	1,160	1,677	1,963	2,280	2,622	3,103	3,504	4,539	5,652	6,666
Electrical machinery															
Balance	804	891	946	1,074	1,222	1,020	883	962	792	729	728	512	321	533	1,602
Export	1,090	1,225	1,361	1,493	1,665	1,660	1,899	2,098	2,284	2,677	2,999	3,067	3,698	5,032	7,019
Import	286	334	415	419	443	640	1,016	1,136	1,492	1,948	2,271	2,555	3,377	4,499	5,417
Aircraft															
Balance	970	766	857	726	791	997	828	1,271	2,015	2,140	2,382	3,049	2,580	3,556	5,256
Export	1,024	903	980	817	874	1,137	1,101	1,519	2,309	2,423	2,656	3,387	2,995	4,119	5,766
Import	54	137	123	91	83	140	273	248	294	283	274	338	415	563	510
Professional and scientific instruments															
Balance	214	241	266	290	306	413	488	522	530	609	653	674	668	822	1,290
Export	321	358	411	447	504	634	748	807	872	1,012	1,107	1,166	1,313	1,632	2,209
Import	107	117	145	157	198	221	260	285	342	403	454	492	645	810	919

SOURCE: U.S. Department of Commerce, Domestic and International Business Administration, *Overseas Business Reports*, April 1975 and April 1972.

Table 1-21. U.S. trade balance with selected nations in R&D-intensive manufactured products, 1966-73
(Dollars in millions)

Nations	1966	1967	1968	1969	1970	1971	1972	1973
Developing nations								
Balance	4,053	4,033	4,430	4,445	4,928	5,087	5,277	6,675
Export	4,316	4,332	4,822	5,002	5,679	5,996	6,765	8,968
Import	263	299	392	547	751	909	1,488	2,293
Western Europe								
Balance	1,890	2,283	2,566	2,986	3,942	3,599	3,089	4,165
Export	3,865	4,359	5,020	5,655	6,927	6,861	7,345	9,597
Import	1,975	2,076	2,454	2,669	2,985	3,262	4,256	5,432
Canada								
Balance	1,800	1,760	1,719	1,914	1,684	1,865	2,333	3,011
Export	2,838	2,983	3,142	3,478	3,513	3,914	4,678	5,741
Import	1,038	1,223	1,423	1,564	1,829	2,049	2,345	2,730
Japan								
Balance	-133	-115	-200	-324	-224	-516	-971	-839
Export	661	772	930	1,180	1,536	1,520	1,639	2,216
Import	794	887	1,130	1,504	1,760	2,036	2,610	3,055

SOURCE: U.S. Department of Commerce, Domestic and International Business Administration, *Overseas Business Reports*, June 1974 and August 1973.

Table 2-1. National R&D expenditures, 1960-74
[Dollars in billions]

Year	Current dollars	Constant dollars[1]
1960	$13.6	$15.4
1961	14.3	16.1
1962	15.4	17.1
1963	17.1	18.8
1964	18.9	20.4
1965	20.1	21.3
1966	21.9	22.6
1967	23.2	23.2
1968	24.7	23.7
1969	26.7	23.6
1970	26.0	22.6
1971	25.7	22.2
1972	28.4	22.9
1973	30.4	23.2
1974 (est.)	32.0	22.1

[1] GNP implicit price deflators used to convert current dollars to constant 1967 dollars.

SOURCE: National Science Foundation, *National Patterns of R&D Resources, 1953-75* (NSF 75-307).

Table 2-2. Scientists and engineers[1] employed in R&D, by sector, 1961-74
[In thousands]

Yearly average	Total	Federal Government	Industry	Universities and colleges	FFRDC's[2]	Other nonprofit institutions
1961	425.7	51.1	312.0	42.4	9.1	11.1
1965	494.1	61.8	348.4	53.4	11.1	19.4
1968	550.4	68.1	381.9	66.0	11.2	23.2
1969	558.2	69.9	385.6	68.3	11.6	22.8
1970	549.5	69.8	375.4	68.5	11.5	24.3
1971	529.7	66.5	358.3	68.4	11.5	25.0
1972	521.5	65.2	352.6	66.5	12.0	25.2
1973	523.1	62.3	359.2	64.6	12.4	24.6
1974 (est.) ...	527.8	65.0	359.5	66.8	12.1	24.4

[1] Full-time-equivalent basis, excluding those employed in State and local agencies, calculated as the yearly average. Graduate students are included.
[2] Federally Funded Research and Development Centers administered by universities.

SOURCE: National Science Foundation, *National Patterns of R&D Resources, 1953-75* (NSF 75-307).

Table 2-3. National R&D expenditures as a percent of GNP by source, 1960-74
[Current dollars in billions]

Year	Gross National Product (GNP)	All sources: Total R&D	All sources: R&D as a percent of GNP	Federal sources: Total R&D	Federal sources: R&D as a percent of GNP	All other sources: Total R&D	All other sources: R&D as a percent of GNP
1960	$503.7	$13.6	2.70	$8.8	1.75	$4.8	0.95
1961	520.1	14.3	2.75	9.3	1.79	5.1	0.98
1962	560.3	15.4	2.75	9.9	1.77	5.5	0.98
1963	590.5	17.1	2.90	11.2	1.90	5.9	1.00
1964	632.4	18.9	2.99	12.6	1.99	6.3	1.00
1965	684.9	20.1	2.93	13.0	1.90	7.1	1.04
1966	749.9	21.9	2.92	14.0	1.87	7.9	1.05
1967	793.9	23.2	2.92	14.4	1.81	8.8	1.11
1968	864.2	24.7	2.86	15.0	1.74	9.7	1.12
1969	930.3	25.7	2.76	14.9	1.60	10.8	1.16
1970	977.1	26.0	2.66	14.8	1.51	11.3	1.16
1971	1,054.9	26.7	2.53	15.0	1.42	11.8	1.12
1972	1,158.0	28.4	2.45	15.9	1.37	12.5	1.08
1973	1,294.9	30.4	2.35	16.5	1.27	14.0	1.08
1974 (est.)	1,396.7	32.0	2.29	17.0	1.22	15.1	1.08

NOTE: Detail may not add to totals because of rounding.

SOURCE: National Science Foundation, *National Patterns of R&D Resources, 1953-75* (NSF 75-307) and *The Budget of the United States Government, Fiscal Year 1976.*

Table 2-4. National expenditures for R&D by source, 1960-74
[Dollars in millions]

Year	Total	Federal government	Industry	Universities and colleges	Other nonprofit institutions
	Current dollars				
1960	$13,551	$8,752	$4,508	$149	$142
1961	14,346	9,264	4,749	165	168
1962	15,426	9,926	5,114	185	201
1963	17,093	11,219	5,449	207	218
1964	18,894	12,553	5,880	235	226
1965	20,091	13,033	6,539	267	252
1966	21,894	13,990	7,317	303	284
1967	23,205	14,420	8,134	345	306
1968	24,669	14,952	8,997	391	329
1969	25,686	14,914	9,998	420	354
1970	26,047	14,764	10,434	461	388
1971	26,745	14,982	10,817	529	417
1972	28,402	15,875	11,508	576	443
1973	30,427	16,472	12,880	604	471
1974 (est.)	32,045	16,955	13,916	683	491
	Constant 1967 dollars[1]				
1960	$15,427	$9,964	$5,132	$170	$162
1961	16,124	10,412	5,338	185	189
1962	17,147	11,034	5,685	206	223
1963	18,756	12,310	5,979	227	239
1964	20,410	13,561	6,352	254	244
1965	21,310	13,824	6,936	283	267
1966	22,594	14,438	7,551	313	293
1967	23,205	14,420	8,134	345	306
1968	23,717	14,376	8,650	376	316
1969	23,560	13,680	9,171	385	325
1970	22,648	12,837	9.072	401	337
1971	22,249	12,463	8,998	440	347
1972	22,857	12,776	9,261	464	357
1973	23,186	12,552	9,815	460	359
1974 (est.)	22,143	11,716	9,616	472	339

[1] GNP implicit price deflators used to convert current dollars to constant 1967 dollars.

NOTE: Detail may not add to totals because of rounding.

SOURCE: National Science Foundation, *National Patterns of R&D Resources* (NSF 75-307).

Table 2-5. National expenditures for R&D by performer, 1960-74
[Dollars in millions]

Year	Total	Federal government	Industry	Universities and colleges	FFRDC's[1]	Other nonprofit institutions
			Current dollars			
1960	$13,551	$1,726	$10,509	$646	$360	$310
1961	14,346	1,874	10,908	763	410	391
1962	15,426	2,098	11,464	904	470	490
1963	17,093	2,279	12,630	1,081	530	573
1964	18,894	2,838	13,512	1,275	629	640
1965	20,091	3,093	14,185	1,474	629	710
1966	21,894	3,220	15,548	1,715	630	781
1967	23,205	3,396	16,385	1,921	673	830
1968	24,669	3,493	17,429	2,149	719	879
1969	25,686	3,503	18,308	2,220	725	930
1970	26,047	3,855	18,062	2,335	737	1,058
1971	26,745	4,156	18,311	2,500	716	1,062
1972	28,402	4,482	19,371	2,675	764	1,110
1973	30,427	4,619	20,937	2,934	817	1,120
1974 (est.)	32,045	4,900	22,020	3,008	865	1,252
			Constant 1967 dollars[2]			
1960	$15,427	$1,965	$11,964	$735	$410	$353
1961	16,124	2,106	12,260	858	461	439
1962	17,147	2,332	12,743	1,005	522	545
1963	18,756	2,501	13,858	1,186	582	629
1964	20,410	3,066	14,597	1,377	679	691
1965	21,310	3,281	15,046	1,563	667	753
1966	22,594	3,323	16,045	1,770	650	806
1967	23,205	3,396	16,385	1,921	673	830
1968	23,717	3,358	16,757	2,066	691	845
1969	23,560	3,213	16,793	2,036	665	853
1970	22,648	3,352	15,705	2,030	641	920
1971	22,249	3,457	15,233	2,080	596	883
1972	22,857	3,607	15,589	2,153	615	893
1973	23,186	3,520	15,954	2,236	623	853
1974 (est.)	22,143	3,386	15,216	2,078	598	865

[1] Federally Funded Research and Development Centers administered by universities.
[2] GNP implicit price deflators used to convert current dollars to constant 1967 dollars.

NOTE: Detail may not add to totals because of rounding.

SOURCE: National Science Foundation, *National Patterns of R&D Resources (NSF 75-307).*

Table 2-6. National R&D expenditures, by character of work, 1960-74
[Dollars in millions]

Year	Current dollars			Constant 1967 dollars[1]		
	Basic research	Applied research	Develop-ment	Basic research	Applied research	Develop-ment
1960	$1,183	$3,057	$9,311	$1,347	$3,480	$10,600
1961	1,378	3,115	9,853	1,549	3,501	11,075
1962	1,695	3,727	10,004	1,884	4,143	11,120
1963	1,974	3,825	11,294	2,166	4,197	12,392
1964	2,301	4,238	12,355	2,486	4,578	13,347
1965	2,572	4,470	13,049	2.728	4,741	13,841
1966	2,825	4,747	14,322	2,915	4,899	14,780
1967	3,029	4,968	15,208	3,029	4,968	15,208
1968	3,286	5,356	16,027	3,159	5,150	15,409
1969	3,378	5,533	16,775	3,099	5,075	15,387
1970	3,548	5,892	16,607	3,085	5,123	14,440
1971	3,544	6,047	17,154	2,948	5,030	14,270
1972	3,705	6,272	18,425	2,982	5,047	14,828
1973	3,800	6,839	19,788	2,896	5,211	15,079
1974 (est.)	3,991	7,460	20,594	2,758	5,155	14,230

[1] GNP implicit price deflators used to convert current dollars to constant 1967 dollars.

SOURCE: National Science Foundation, *National Patterns of R&D Resources, 1953-75 (NSF 75-307).*

Table 2-7a. Basic research expenditures by source, 1960-74
[Dollars in millions]

Year	Total	Federal Government	Industry	Universities and colleges	Other nonprofit institutions
			Current dollars		
1960	$1,183	$693	$331	$72	$87
1961	1,378	841	350	85	102
1962	1,695	1,091	382	102	120
1963	1,974	1,310	414	121	129
1964	2,301	1,595	424	144	138
1965	2,572	1,817	448	164	143
1966	2,825	1,986	496	196	147
1967	3,029	2,173	477	223	156
1968	3,286	2,327	518	276	165
1969	3,378	2,386	519	298	175
1970	3,548	2,469	536	350	193
1971	3,544	2,379	556	400	209
1972	3,705	2,528	528	428	221
1973	3,800	2,605	561	416	218
1974 (est.)	3,991	2,724	594	434	239
			Constant 1967 dollars[1]		
1960	$1,347	$789	$377	$82	$99
1961	1,549	945	393	96	115
1962	1,884	1,213	425	113	133
1963	2,166	1,437	454	133	142
1964	2,486	1,723	458	156	149
1965	2,728	1,927	475	174	152
1966	2,916	2,050	512	202	152
1967	3,029	2,173	477	223	156
1968	3,159	2,237	498	265	159
1969	3,099	2,189	476	273	161
1970	3,085	2,147	466	304	168
1971	2,949	1,979	463	333	174
1972	2,981	2,034	425	344	178
1973	2,895	1,985	427	317	166
1974 (est.)	2,757	1,882	410	300	165

[1] GNP implicit price deflators used to convert current dollars to constant 1967 dollars.

SOURCE: National Science Foundation, *National Patterns of R&D Resources; 1953-75* (NSF 75-307).

Table 2-7b. Applied research expenditures by source, 1960-74
[Dollars in millions]

Year	Total	Federal Government	Industry	Universities and colleges	Other nonprofit institutions
			Current dollars		
1960	$3,057	$1,725	$1,228	$66	$38
1961	3,115	1,804	1,197	69	45
1962	3,727	2,127	1,473	70	57
1963	3,825	2,205	1,487	72	61
1964	4,238	2,503	1,596	77	62
1965	4,470	2,653	1,658	88	71
1966	4,747	2,729	1,844	89	85
1967	4,968	2,874	1,895	102	97
1968	5,356	3,020	2,132	97	107
1969	5,533	2,982	2,327	105	119
1970	5,892	3,258	2,406	98	130
1971	6,047	3,313	2,476	115	143
1972	6,272	3,387	2,601	132	152
1973	6,839	3,670	2,835	158	176
1974 (est.)	7,460	3,992	3,080	214	174
			Constant 1967 dollars[1]		
1960	$3,480	$1,964	$1,398	$75	$43
1961	3,502	2,028	1,345	78	51
1962	4,142	2,364	1,637	78	63
1963	4,197	2,419	1,632	79	67
1964	4,578	2,704	1,724	83	67
1965	4,741	2,814	1,759	93	75
1966	4,899	2,816	1,903	92	88
1967	4,968	2,874	1,895	102	97
1968	5,150	2,904	2,050	93	103
1969	5,074	2,735	2,134	96	109
1970	5,123	2,833	2,092	85	113
1971	5,031	2,756	2,060	96	119
1972	5,047	2,726	2,093	106	122
1973	5,211	2,797	2,160	120	134
1974 (est.)	5,154	2,758	2,128	148	120

[1] GNP implicit price deflators used to convert current dollars to constant 1967 dollars.

SOURCE: National Science Foundation, *National Patterns of R&D Resources*, (NSF 75-307).

Table 2-7c. Development expenditures by source, 1960-74
[Dollars in millions]

Year	Total	Federal Government	Industry	Universities and colleges	Other nonprofit institutions
			Current dollars		
1960	$9,311	$6,334	$2,949	$11	$17
1961	9,853	6,619	3,202	11	21
1962	10,004	6,708	3,259	13	24
1963	11,294	7,704	3,548	14	28
1964	12,355	8,455	3,860	14	26
1965	13,049	8,563	4,433	15	38
1966	14,322	9,275	4,977	18	52
1967	15,208	9,373	5,762	20	53
1968	16,027	9,606	6,347	17	57
1969	16,775	9,546	7,152	17	60
1970	16,607	9,037	7,492	13	65
1971	17,154	9,290	7,785	14	65
1972	18,425	9,960	8,379	16	70
1973	19,788	10,197	9,484	30	77
1974 (est.)	20,594	10,239	10,242	35	78
			Constant 1967 dollars[1]		
1960	$10,600	$7,211	$3,357	$13	$19
1961	11,075	7,440	3,599	12	24
1962	11,121	7,457	3,623	14	27
1963	12,392	8,453	3,893	15	31
1964	13,347	9,134	4,170	15	28
1965	13,841	9,083	4,702	16	40
1966	14,781	9,572	5,136	19	54
1967	15,208	9,373	5,762	20	53
1968	15,409	9,236	6,102	16	55
1969	15,387	8,756	6,560	16	55
1970	14,440	7,858	6,514	11	57
1971	14,270	7,728	6,476	12	54
1972	14,827	8,015	6,743	13	56
1973	15,079	7,770	7,227	23	59
1974 (est.)	14,230	7,075	7,077	24	54

[1] GNP implicit price deflators used to convert current dollars to constant 1967 dollars.

SOURCE: National Science Foundation, *National Patterns of R&D Resources, 1953-75* (NSF 75-307).

Table 2-8. Federal expenditures[1] for research, development and R&D plant, as a percent of total Federal outlays, and as a percent of the relatively controllable portion of the Federal outlays, 1960-74

Year	Federal R&D expenditures[2]	Total Federal outlays[2]	Expenditures as a percent of total Federal outlays	Expenditures as a percent of controllable outlays
1960	$ 7.7	$ 92.2	8.4	NA
1961	9.3	97.8	9.5	NA
1962	10.4	106.8	9.7	NA
1963	12.0	111.3	10.8	NA
1964	14.7	118.6	12.4	NA
1965	14.9	118.4	12.6	NA
1966	16.0	134.7	11.9	NA
1967	16.9	158.3	10.7	16.4
1968	17.0	178.8	9.5	14.7
1969	16.4	184.5	8.9	14.6
1970	15.7	196.6	8.0	13.7
1971	16.0	211.4	7.6	14.0
1972	16.7	231.9	7.2	13.9
1973	17.5	246.5	7.1	15.1
1974 (est.)	18.6	274.7	6.8	14.8

[1] Reported by Federal agencies.
[2] In billions of current dollars.

NOTE: NA = not available.

SOURCE: National Science Foundation, *Federal Funds for Research, Development, and Other Scientific Activities*, Vol. XXIII (NSF 74-320) and earlier volumes.

Table 2-9. Federal obligations for R&D, by major function, 1969-74
[Dollars in millions]

Function	1969	1970	1971	1972	1973	1974 (est.)
	Current dollars					
Total	$15,641	$15,340	$15,564	$16,512	$16,821	$17,743
National defense	8,354	7,976	8,106	8,898	8,998	9,180
Space	3,732	3,510	2,893	2,714	2,601	2,510
Total civilian R&D	3,556	3,855	4,564	4,900	5,222	6,055
	Constant 1967 dollars[1]					
Total	$14,347	$13,338	$12,947	$13,288	$12,818	$12,260
National defense	7,663	6,935	6,743	7,161	6,857	6,343
Space	3,423	3,052	2,407	2,184	1,982	1,734
Total civilian R&D	3,262	3,352	3,797	3,943	3,979	4,184

[1] GNP implicit price deflators used to convert current dollars to constant 1967 dollars.

NOTE: Detail may not add to totals because of rounding.

SOURCE: National Science Foundation, *An Analysis of Federal R&D Funding by Function, 1969-75* (NSF 74-313).

Table 2-10. Federal obligations for R&D by function, 1969 and 1974
[Dollars in millions]

Function	1969	1970	1971	1972	1973	1974 (est.)
	Current dollars					
National defense	$8,354	$7,976	$8,106	$8,898	$8,998	$9,180
Space	3,732	3,510	2,893	2,714	2,601	2,510
Health	1,111	1,111	1,319	1,564	1,592	2,085
Environment	321	359	475	547	678	738
Transportation and communication	461	593	782	617	625	689
Science and technology base	518	529	531	606	610	648
Natural resources	412	462	553	625	618	633
Energy development and conversion	328	317	324	383	442	574
Education	158	151	198	208	231	227
Income security & social services	93	102	123	115	151	131
Area & community development & housing	49	91	108	102	117	127
Economic growth & productivity	73	99	109	78	90	117
Crime prevention & control	5	9	10	25	35	52
International cooperation & development	27	32	32	30	33	34
	Constant 1967 dollars[1]					
National defense	$7,663	$6,935	$6,743	$7,161	$6,857	$6,343
Space	3,423	3,052	2,407	2,184	1,982	1,734
Health	1,019	966	1,097	1,259	1,213	1,441
Environment	294	312	395	440	517	510
Transportation and communication	423	516	651	497	476	476
Science and technology base	475	460	442	488	465	448
Natural resources	378	402	460	503	471	437
Energy development and conversion	301	276	270	308	337	397
Education	145	131	165	167	176	157
Income security & social services	85	89	102	93	115	91
Area & community development & housing	45	79	90	82	89	88
Economic growth & productivity	67	86	91	63	69	81
Crime prevention & control	5	8	8	20	27	36
International cooperation & development	25	28	27	24	25	23

[1] GNP implicit price deflators used to convert current dollars to constant 1967 dollars.

SOURCE: National Science Foundation, *An Analysis of Federal R&D Funding by Function, 1969-75* (NSF 74-313).

Table 2-11. Federal obligations for civilian R&D, by character of work, 1970 and 1974
[Dollars in millions]

Character	1970	1974 (est.)
	Current dollars	
Total R&D	$3,845.6	$6,040.9
Basic research	1,200.1	1,636.8
Applied research	1,671.4	2,733.5
Development	974.1	1,670.6
	Constant 1967 dollars[1]	
Total R&D	$3,343.8	$4,174.2
Basic research	1,043.5	1,131.0
Applied research	1,453.3	1,888.8
Development	847.0	1,154.4

[1] GNP implicit price deflators used to convert current dollars to constant 1967 dollars.

SOURCE: National Science Foundation, special tabulations.

Table 2-12. Proportion of NSF and NIH[1] research project grant funds allocated for permanent laboratory equipment, fiscal years 1966-74
[Percent]

Year	NSF	NIH
1966	11.2	11.7
1967	8.6	11.8
1968	7.5	9.5
1969	7.0	7.5
1970	6.1	5.9
1971	6.3	6.2
1972	5.6	6.6
1973	5.5	4.9
1974	5.4	5.7

[1] Includes the National Cancer Institute, the National Institute of General Medical Sciences, and the National Heart and Lung Institute.

SOURCE: National Science Foundation, *Databook*, annual series, and National Institutes of Health, unpublished data.

Table 2-13. NSF obligations for permanent laboratory equipment, 1966-74
[Dollars in millions]

Year	Current dollars	Constant 1967 dollars[1]
1966	$17.6	$18.2
1967	14.4	14.4
1968	12.8	12.3
1969	12.3	11.3
1970	9.9	8.6
1971	11.0	9.2
1972	13.6	10.9
1973	14.7	11.2
1974	15.2	10.5

[1] GNP implicit price deflators used to convert current dollars to constant 1967 dollars.

SOURCE: National Science Foundation, *Databook*, annual series.

Table 2-14. Federal expenditures for R&D plant, 1960-74
[Dollars in millions]

Year	Current dollars	Constant 1967 dollars[1]
1960	$528.3	$596.9
1961	548.5	609.4
1962	779.1	857.1
1963	1,168.3	1,269.9
1964	1,098.5	1,177.4
1965	1,077.4	1,134.1
1966	1,047.8	1,081.3
1967	786.1	786.1
1968	715.9	691.7
1969	652.2	603.9
1970	578.9	508.3
1971	612.7	511.4
1972	564.4	454.4
1973	638.0	494.6
1974 (est.)	894.1	640.9

[1] GNP implicit price deflators used to convert current dollars to constant 1967 dollars.

SOURCE: National Science Foundation, *Federal Funds for Research, Development and Other Scientific Activities*, Vol. XXIII (NSF 74-320-A) and earlier volumes.

Table 2-15. Federal obligations for R&D plant, by performer, 1962-74

[Dollars in millions]

Performer	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974 (est.)
	Current dollars												
Total	777.6	1,186.0	1,177.5	1,131.6	858.3	620.1	603.8	669.0	524.4	611.2	602.1	774.3	971.9
Federal intramural	619.9	974.4	974.5	913.0	629.0	239.0	294.2	260.4	166.0	200.0	246.6	323.8	409.5
Industry	NA	NA	NA	NA	NA	NA	81.7	141.7	102.3	167.4	142.4	221.8	339.1
Universities & colleges	NA	NA	97.5	141.6	162.9	111.7	98.1	61.9	56.1	49.2	45.3	42.6	49.2
FFRDC's (administered by universities)	NA	NA	36.0	50.2	31.1	138.8	101.7	176.6	169.0	178.7	130.4	162.3	134.1
Nonprofit institutions	NA	NA	NA	NA	NA	NA	20.9	25.8	28.8	5.8	30.0	18.8	36.2
	Constant 1967 dollars[1]												
Total	864.4	1,301.3	1,272.0	1,200.3	885.8	620.1	580.5	613.6	456.0	508.4	484.5	590.0	671.6
Federal intramural	689.1	1,069.1	1,052.7	968.4	649.1	239.0	282.9	238.0	144.3	166.4	198.5	246.7	283.0
Industry	NA	NA	NA	NA	NA	NA	78.6	130.0	88.9	139.3	114.6	169.0	234.3
Universities & colleges	NA	NA	105.3	150.2	168.1	111.7	94.3	56.8	48.8	40.9	36.5	32.5	34.0
FFRDC's (administered by universities)	NA	NA	38.9	53.2	32.1	138.8	97.8	162.0	146.9	148.7	104.9	123.7	92.7
Nonprofit institutions	NA	NA	NA	NA	NA	NA	20.1	23.7	25.0	4.8	24.1	14.3	25.0

[1] GNP implicit price deflators used to convert current dollars to constant 1967 dollars.

NOTE: NA = not available.

SOURCE: National Science Foundation, *Federal Funds for Research, Development and Other Scientific Activities*, Vol. XXIII (NSF 74-320-A) and earlier volumes.

Table 2-16. Federal obligations for R&D plant as a percent of Federal obligations for total R&D, by performer, 1962-74

Performer	Percent												
	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974 (est.)
Total	8	9	8	8	6	4	4	4	3	4	4	5	5
Federal intramural	30	43	34	30	20	7	8	7	4	5	6	7	8
Industry	NA	NA	NA	NA	NA	NA	1	2	1	2	2	3	4
Universities and colleges	NA	NA	9	12	12	8	7	4	4	3	2	2	2
FFRDC's (administered by universities)	NA	NA	6	8	5	21	14	24	23	25	17	22	17
Nonprofit institutions	NA	NA	NA	NA	NA	NA	3	4	4	1	4	2	4

NOTE: NA = not available.

SOURCE: National Science Foundation, *Federal Funds for Research, Development and Other Scientific Activities*, Vol. XXIII (NSF 74-320-A), and earlier volumes.

Table 2-17. Federal obligations for scientific and technical information activities compared with total Federal R&D obligations, 1960-74

Year	Obligations for scientific and technical information activities (in millions)		Ratio of these obligations to total Federal R&D obligations
	Current dollars	Constant 1967 dollars[1]	
1960	$ 76	$ 87	.010
1961	92	103	.010
1962	129	143	.013
1963	165	181	.013
1964	203	219	.014
1965	225	239	.015
1966	278	287	.018
1967	324	324	.020
1968	359	345	.023
1969	362	332	.023
1970	387	336	.025
1971	398	331	.026
1972	419	337	.025
1973	438	334	.026
1974 (est.)	468	323	.026

[1] GNP implicit price deflators used to convert current dollars to constant 1967 dollars.

SOURCE: National Science Foundation, *Federal Funds for Research, Development and Other Scientific Activities, Fiscal Years 1973, 1974 and 1975*, Vol. XXIII (NSF 75-320-A) and earlier volumes.

Table 2-18. Federal obligations for scientific and technical information activities, by agency, 1960-74

[Dollars in millions]

Agency	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974 (est.)
	Current dollars														
Total	$76	$92	$129	$165	$203	$225	$278	$324	$359	$362	$387	$398	$419	$438	$468
Dept. of Defense	16	23	38	53	84	99	119	139	155	147	145	141	150	161	158
Dept. of Health, Education and Welfare	10	12	24	27	24	24	37	53	60	65	66	73	68	67	82
Dept. of Commerce	23	27	28	31	33	37	42	46	47	52	60	69	78	85	93
Library of Congress	5	6	6	8	9	10	13	13	17	20	22	25	30	32	35
National Aeronautics and Space Administration	1	3	7	14	20	19	23	24	27	28	27	27	27	25	24
Dept. of the Interior	4	4	5	7	8	9	10	12	14	13	13	14	14	16	21
National Science Foundation	7	7	10	10	12	13	16	12	16	12	15	14	12	11	10
Dept. of Agriculture	4	4	4	4	5	6	6	14	8	9	10	10	11	13	13
Other agencies	6	6	7	11	8	8	12	11	15	16	29	25	29	28	32
	Constant 1967 dollars[1]														
Total	$87	$102	$144	$181	$221	$238	$286	$324	$344	$333	$335	$331	$338	$333	$324
Dept. of Defense	18	26	42	58	91	105	123	139	149	135	126	117	121	123	109
Dept. of Health, Education and Welfare	11	13	27	30	16	25	38	53	58	60	57	61	55	51	57
Dept. of Commerce	26	30	31	34	36	39	43	46	45	48	52	57	63	65	64
Library of Congress	6	7	7	9	10	11	13	13	16	18	19	21	24	24	24
National Aeronautics and Space Administration	1	3	8	15	22	20	24	24	26	26	23	22	22	19	17
Dept. of the Interior	5	4	6	8	9	10	10	12	13	12	11	12	11	12	15
National Science Foundation	8	8	11	11	13	14	17	12	15	11	13	12	10	8	7
Dept. of Agriculture	5	4	4	4	5	6	6	14	8	8	9	8	9	10	9
Other agencies	7	7	8	12	9	8	12	11	14	15	25	21	23	21	22

[1] GNP implicit price deflators used to convert current dollars to constant 1967 dollars.

NOTE: Detail may not add to totals because of rounding.

SOURCE: National Science Foundation, *Federal Funds for Research, Development and Other Scientific Activities, Fiscal Years 1973, 1974 and 1975.* Vol. XXIII (NSF 74-320-A) and earlier volumes.

Table 3-1. Basic research expenditures, 1960-74
[Dollars in millions]

Year	Current dollars	Constant 1967 dollars[1]
1960	$1,183	$1,347
1961	1,378	1,549
1962	1,695	1,884
1963	1,974	2,166
1964	2,301	2,486
1965	2,572	2,728
1966	2,825	2,915
1967	3,029	3,029
1968	3,286	3,159
1969	3,378	3,099
1970	3,548	3,085
1971	3,544	2,948
1972	3,705	2,982
1973	3,800	2,896
1974(est.)	3,991	2,758

[1] GNP implicit price deflators used to convert current dollars to constant 1967 dollars.

SOURCE: National Science Foundation, *National Patterns of R&D Resources*, 1953-75 (NSF 75-307).

Table 3-2. Basic research expenditures, by performer, 1960-74
[Dollars in millions]

Year	Total	Universities and colleges	Federal Government	Industry	FFRDC's[1]	Nonprofit institutions
			Current dollars			
1960	$1,183	$ 433	$160	$376	$ 97	$117
1961	1,378	536	206	395	115	126
1962	1,695	659	251	488	136	161
1963	1,974	814	299	522	159	180
1964	2,301	1,003	364	549	191	194
1965	2,572	1,138	424	592	208	210
1966	2,825	1,303	445	624	227	226
1967	3,029	1,457	472	629	250	221
1968	3,286	1,649	502	642	276	217
1969	3,378	1,707	565	618	275	213
1970	3,548	1,796	646	629	269	208
1971	3,544	1,914	535	610	260	225
1972	3,705	2,024	607	579	250	245
1973	3,800	2,058	585	605	297	255
1974(est.)	3,991	2,151	635	640	291	274
			Constant 1967 dollars[2]			
1960	$1,347	$ 492	$182	$428	$110	$133
1961	1,549	602	232	444	129	142
1962	1,884	733	279	542	151	179
1963	2,165	893	328	573	174	197
1964	2,486	1,084	393	593	206	210
1965	2,729	1,207	450	628	221	223
1966	2,915	1,345	459	644	234	233
1967	3,029	1,457	472	629	250	221
1968	3,159	1,586	483	617	265	209
1969	3,098	1,566	518	567	252	195
1970	3,086	1,562	562	547	234	181
1971	2,947	1,592	445	507	216	187
1972	2,981	1,629	488	466	201	197
1973	2,895	1,568	446	461	226	194
1974(est.)	2,757	1,486	439	442	201	189

[1] Federally Funded Research and Development Centers administered by universities.
[2] GNP implicit price deflators used to convert current dollars to constant 1967 dollars.

NOTE: Detail may not add to totals because of rounding.

SOURCE: National Science Foundation, *National Patterns of R&D Resources, 1953-75* (NSF 75-307).

Table 3-3. Basic research expenditure, by source 1960-74
[Dollars in millions]

Year	Total	Federal Government	Industry	Universities and colleges[1]	Nonprofit institutions
	Current dollars				
1960	$1,183	$ 693	$331	$ 72	$ 87
1961	1,378	841	350	85	102
1962	1,695	1,091	382	102	120
1963	1,974	1,310	414	121	129
1964	2,301	1,595	424	144	138
1965	2,572	1,817	448	164	143
1966	2,825	1,986	496	196	147
1967	3,029	2,173	477	223	156
1968	3,286	2,327	518	276	165
1969	3,378	2,386	519	298	175
1970	3,548	2,469	536	350	193
1971	3,544	2,379	556	400	209
1972	3,705	2,528	528	428	221
1973	3,800	2,605	561	416	218
1974(est.)	3,991	2,724	594	434	239
	Constant 1967 dollars[2]				
1960	$1,347	$ 789	$377	$ 82	$ 99
1961	1,549	945	393	96	115
1962	1,884	1,213	425	113	133
1963	2,166	1,437	454	133	142
1964	2,486	1,723	458	156	149
1965	2,728	1,927	475	174	152
1966	2,915	2,050	512	202	152
1967	3,029	2,173	477	223	156
1968	3,159	2,237	498	265	159
1969	3,098	2,189	476	273	161
1970	3,086	2,147	466	304	168
1971	2,947	1,979	463	333	174
1972	2,981	2,034	425	344	178
1973	2,895	1,985	427	317	166
1974(est.)	2,757	1,882	410	300	182

[1] Includes State and local government sources.
[2] GNP implicit price deflators used to convert current dollars to constant 1967 dollars.

NOTE: Detail may not add to totals because of rounding.

SOURCE: National Science Foundation, *National Patterns of R&D Resources, 1953-75* (NSF 75-307).

Table 3-4. Federal obligations for basic research as a percent of each agency's R&D obligations, by agency, 1960-74

Year	All agencies	USDA	DOD	HEW	AEC	NASA[1]	NSF	All other agencies
	Basic research as a percent of all R&D obligations							
1960	8	27	3	32	14	26	91	19
1961	9	29	3	32	20	24	92	19
1962	11	32	3	33	19	22	91	20
1963	11	33	3	36	20	16	92	20
1964	11	36	3	35	19	12	91	22
1965	12	40	4	35	21	11	91	22
1966	12	40	4	32	23	11	91	18
1967	12	40	4	32	24	12	91	15
1968	13	39	3	32	21	15	89	17
1969	13	41	4	29	20	17	91	15
1970	13	41	3	32	21	17	85	12
1971	14	39	3	27	21	21	81	9
1972	15	39	3	26	21	24	81	12
1973	14	39	3	25	20	25	82	10
1974(est.)	15	39	3	25	20	24	79	10
	Federal obligations for basic research (Current dollars in millions)							
1960	$ 610	$ 34	$168	$103	$104	$ 97	$ 68	$ 35
1961	825	41	173	137	167	190	77	39
1962	1,106	50	204	190	192	316	104	50
1963	1,389	56	231	236	219	447	141	59
1964	1,567	68	241	274	238	524	155	66
1965	1,690	90	263	303	258	528	171	77
1966	1,840	94	262	326	281	559	223	95
1967	2,004	100	284	372	302	603	239	104
1968	2,056	100	263	397	282	656	252	106
1969	2,077	107	276	371	285	678	248	112
1970	2,042	116	247	388	287	637	245	122
1971	2,132	118	262	397	277	680	273	125
1972	2,411	137	270	461	268	768	368	139
1973	2,420	143	258	458	275	769	392	125
1974(est.)	2,569	150	253	588	286	734	421	138
	Federal obligations for all R&D (Current dollars in millions)							
1960	$ 7,552	$126	$5,712	$ 320	$ 762	$ 369	$ 75	$ 189
1961	9,059	143	6,574	429	850	777	84	202
1962	10,290	157	6,723	577	1,029	1,439	114	251
1963	12,495	168	7,286	656	1,078	2,857	154	295
1964	14,225	189	7,262	777	1,236	4,287	170	305
1965	14,614	225	6,797	869	1,241	4,952	187	344
1966	15,320	235	7,024	1,014	1,212	5,050	244	541
1967	16,529	253	8,049	1,147	1,259	4,867	262	694
1968	15,921	254	7,709	1,252	1,369	4,429	284	625
1969	15,641	260	7,696	1,297	1,406	3,963	274	744
1970	15,340	281	7,360	1,221	1,346	3,800	289	1,043
1971	15,564	305	7,509	1,476	1,303	3,258	337	1,377
1972	16,512	350	8,318	1,751	1,298	3,157	455	1,183
1973	16,821	367	8,404	1,838	1,363	3,061	480	1,309
1974(est.)	17,743	386	8,599	2,347	1,431	3,026	530	1,425

[1] The large amounts reported by NASA for basic research are due to the substantial cost of support equipment such as spacecraft and launch vehicles peculiar to space exploration, and the statistical proration of costs for tracking and data acquisition.

NOTE: Detail may not add to totals because of rounding.

SOURCE: National Science Foundation, *Federal Funds for Research, Development, and Other Scientific Activities, Fiscal Years 1973, 1974 and 1975.* Volume XXIII (NSF 74-320-A) and earlier volumes.

Table 3-5. Federal obligations for basic research, by agency, 1960-74
[Dollars in millions]

Agency	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974 (est.)
	Current dollars														
Total	$610	$825	$1,106	$1,389	$1,567	$1,690	$1,840	$2,004	$2,056	$2,077	$2,042	$2,132	$2,411	$2,420	$2,569
Department of Agriculture	34	41	50	56	68	90	94	100	100	107	116	118	137	143	150
Department of Defense	168	173	204	231	241	263	262	284	263	276	247	262	270	258	253
Department of Health, Education and Welfare	103	137	190	236	274	303	326	372	397	371	388	397	461	458	588
Atomic Energy Commission	104	167	192	219	238	258	281	302	282	285	287	277	268	275	286
National Aeronautics and Space Administration[1]	97	190	316	447	524	528	559	603	656	678	637	680	768	769	734
National Science Foundation	68	77	104	141	155	171	223	239	252	248	245	273	368	392	421
All other Federal agencies	35	39	50	59	66	77	95	104	106	112	122	125	138	125	138
	Constant 1967 dollars[2]														
Total	$694	$927	$1,229	$1,524	$1,693	$1,793	$1,899	$2,004	$1,977	$1,905	$1,775	$1,774	$1,940	$1,844	$1,775
Department of Agriculture	39	46	56	61	73	95	97	100	96	98	101	98	110	109	104
Department of Defense	191	194	227	253	260	279	270	284	253	253	215	218	217	197	175
Department of Health, Education and Welfare	117	154	211	259	296	321	336	372	382	340	337	330	371	349	406
Atomic Energy Commission	118	188	213	240	257	274	290	302	271	261	250	230	216	210	198
National Aeronautics and Space Administration[1]	110	214	351	490	566	560	577	603	631	622	554	566	618	586	507
National Science Foundation	77	87	116	155	167	181	230	239	242	227	213	227	296	299	291
All other Federal agencies	40	44	56	65	71	82	98	104	102	103	106	104	111	95	95

[1] The large amounts reported by NASA for basic research are due to the substantial cost of support equipment such as spacecraft and launch vehicles peculiar to space exploration, and the statistical prorations of costs for tracking and data acquisition.
[2] GNP implicit price deflators used to convert current dollars to constant 1967 dollars.

NOTE: Detail may not add to totals because of rounding.

SOURCE: National Science Foundation, *Federal Funds for Research, Development and other Scientific Activities, Fiscal Years 1973, 1974, and 1975.* Volume XXIII (NSF 74-320-A) and earlier volumes.

Table 3-6. Federal obligations for basic research, by field of science, 1960-74
[Dollars in millions]

Field of science	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974 (est.)
	Current dollars														
All fields	$610	$825	$1,106	$1,389	$1,567	$1,690	$1,840	$2,004	$2,056	$2,077	$2,042	$2,132	$2,411	$2,420	$2,569
Life sciences	172	238	313	380	424	487	552	612	612	569	576	596	729	758	869
Biological	NA	NA	NA	232	268	328	378	418	418	433	428	450	576	645	728
Clinical medical[1]	NA	NA	NA	148	156	159	174	194	194	134	148	101	128	98	118
Other life sciences	NA	NA	NA	—	—	—	—	—	—	2	—	45	25	15	23
Environmental sciences } Physical sciences }	319	444	603												
Environmental sciences				252	308	263	291	315	342	309	341	393	454	445	430
Physical sciences				515	566	639	667	713	731	819	704	743	783	796	830
Chemistry	NA	NA	NA	86	101	109	119	124	119	132	143	133	181	195	203
Physics	NA	NA	NA	269	271	327	351	381	389	398	353	387	379	389	400
Astronomy	NA	NA	NA	140	174	177	170	180	205	282	204	217	215	202	202
Other physical sciences	NA	NA	NA	20	20	26	27	28	18	7	4	6	8	10	25
Psychology	17	21	28	36	47	58	53	60	55	55	57	49	58	51	62
Mathematical and computer sciences	18	21	26	42	52	57	60	65	67	57	59	52	63	57	56
Engineering	76	82	116	137	135	147	168	178	185	185	234	220	235	206	209
Social sciences	8	11	18	25	34	37	44	57	61	72	65	70	80	78	91
Other sciences	(2)	8	2	2	2	2	4	4	4	11	4	10	9	28	22
	Constant 1967 dollars[3]														
All fields	$694	$927	$1,229	$1,524	$1,693	$1,793	$1,899	$2,004	$1,977	$1,905	$1,775	$1,774	$1,940	$1,844	$1,775
Life sciences	196	268	348	417	458	517	570	612	588	522	501	496	587	578	600
Biological	NA	NA	NA	255	290	348	390	418	402	397	372	374	464	492	503
Clinical medical[1]	NA	NA	NA	162	169	169	180	194	187	123	129	84	103	75	82
Other life sciences	NA	NA	NA	—	—	—	—	—	—	2	—	37	20	11	16
Environmental sciences } Physical sciences }	363	499	670												
Environmental sciences				276	333	279	300	315	329	283	296	327	365	339	297
Physical sciences				565	611	678	688	713	703	751	612	618	630	607	574
Chemistry	NA	NA	NA	94	109	116	123	124	114	121	124	111	146	149	140
Physics	NA	NA	NA	295	293	347	362	381	374	365	307	322	305	296	276
Astronomy	NA	NA	NA	154	188	188	175	180	197	259	177	181	173	154	140
Other physical sciences	A	NA	NA	22	22	28	28	28	17	6	3	5	6	8	17
Psychology	19	24	31	39	51	62	55	60	53	50	50	41	47	39	43
Mathematical and computer sciences	20	24	29	46	56	60	62	65	64	52	51	43	51	43	39
Engineering	87	92	129	150	146	156	173	178	178	170	203	183	189	157	144
Social sciences	9	12	20	27	37	39	45	57	59	66	57	58	64	59	63
Other sciences	(2)	9	2	2	2	2	4	4	4	10	3	8	7	21	15

[1] Includes "other medical sciences".
[2] Less than $50,000.
[3] GNP implicit price deflators used to convert current dollars to constant 1967 dollars.

NOTE: NA = not available.

SOURCE: National Science Foundation, *Federal Funds for Research, Development, and Other Scientific Activities, Fiscal Years 1973, 1974, and 1975.* Volume XXIII (NSF 74-320-A) and earlier volumes.

Table 3-6a. Fields and subfields of Federal obligations for basic research

Field of science	Illustrative subfields
Life sciences	Biological sciences: those which, apart from clinical medical and other medical sciences defined below, deal with the origin, development, structure, function, and interaction of living things.
	Clinical medical sciences: those concerned with the study of pathogenesis, diagnosis, or therapy of a particular disease or abnormal condition in living human subjects under controlled conditions.
	Other medical sciences: those concerned with the study of the causes, effects, prevention, or control of abnormal conditions in man or in his environment as they relate to health, except for the clinical aspects defined above.
	Other life sciences: multidisciplinary projects within the broad field and single discipline projects for which a separate field has not been assigned.
Environmental sciences	Atmospheric sciences: aeronomy, solar, weather modification, extraterrestrial atmospheres, and meteorology.
	Geological sciences: engineering geophysics, general geology, geodesy and gravity, geomagnetism, hydrology, inorganic geochemistry, isotopic geochemistry, organic geochemistry, laboratory geophysics, paleomagnetism, paleontology, physical geography and cartography, seismology and soil sciences.
	Oceanography: chemical oceanography, geological oceanography, physical oceanography, and marine geophysics.
	Other environmental sciences: multidisciplinary projects within the broad field and single discipline projects for which a separate field has not been assigned.
Mathematics	Algebra, analysis, applied mathematics, computer science, foundations and logic, geometry, numerical analysis, statistics, and topology.
Engineering	Aeronautical: aerodynamics.
	Astronautical: aerospace, and space technology.
	Chemical: petroleum, petroleum refining, and process.
	Civil: architectural, hydraulic, hydrologic, marine, sanitary and environmental, structural, and transportation.
	Electrical: communication, electronic, and power.
	Mechanical: engineering mechanics.
	Metallurgy and materials: ceramic, mining, textile, and welding.
	Other engineering: multidisciplinary projects within the broad field and single discipline projects for which a separate field has not been assigned, such as agricultural, industrial and management, nuclear, ocean engineering, and systems.

(Continued)

Table 3-6a. (Continued)

Social sciences	Anthropology: archaeology, cultural and personality, social and ethnology, and applied anthropology.
	Economics: econometrics and economic statistics, history of economic thought, international economics, industrial, labor and agricultural economics, macroeconomics, microeconomics, public finance and fiscal policy, theory, and economic systems and development.
	History: cultural, political, social, and history and philosophy of science.
	Linguistics: anthropological-archaeological, computational, psycholinguistics, and sociolinguistics.
	Political science: area or regional studies, comparative government, history of political ideas, international relations and law, national political and legal systems, political theory, and public administration.
	Sociology: comparative and historical, complex organizations, culture and social structure, demography, group interactions, social problems and social welfare, and sociological theory.
	Other social sciences: multidisciplinary projects within the broad field and single discipline projects for which a separate field has not been assigned, such as research in law and education not elsewhere classified, and socioeconomic geography.
Psychology	Biological aspects: experimental psychology, animal behavior, clinical psychology, comparative psychology, and ethology.
	Social aspects: social psychology, educational, personnel, vocational psychology and testing, industrial and engineering psychology, and development and personality.
	Other psychological sciences: multidisciplinary projects within the broad field and single discipline projects for which a separate field has not been assigned.
Physical sciences	Astronomy: laboratory astrophysics, optical astronomy, radio astronomy, theoretical astrophysics, X-ray, Gamma-ray, and neutrino astronomy.
	Chemistry: inorganic, organo-metallic, organic, and physical.
	Physics: acoustics, atomic and molecular, condensed matter, elementary particles, nuclear structure, optics, and plasma..
	Other physical sciences: multidisciplinary projects within the broad field and single discipline projects for which a separate field has not been assigned.
Other sciences	Multidisciplinary and interdisciplinary projects that cannot be classified within one of the above broad fields of science.

SOURCE: National Science Foundation, *Federal Funds for Research, Development, and Other Scientific Activities, Fiscal Years 1973, 1974, and 1975*. Vol. XXIII (NSF 74-320).

Table 3-7. Basic research expenditures in universities and colleges, by source, 1960-74
[Dollars in millions]

Year	Total	Federal Govern- ment	Industry	All other sources
	Current dollars			
1960	$ 433	$ 299	$24	$110
1961	536	382	25	129
1962	659	481	25	153
1963	814	610	25	179
1964	1,003	767	25	211
1965	1,138	879	26	233
1966	1,303	1,009	27	267
1967	1,457	1,124	31	302
1968	1,649	1,251	36	362
1969	1,707	1,275	39	393
1970	1,796	1,296	40	460
1971	1,914	1,349	46	519
1972	2,024	1,419	51	554
1973	2,058	1,461	58	539
1974(est.)	2,151	1,514	64	573
	Constant 1967 dollars[1]			
1960	$ 492	$ 340	$27	$125
1961	602	429	28	145
1962	733	535	28	170
1963	893	669	27	197
1964	1,084	829	27	228
1965	1,207	932	28	247
1966	1,345	1,041	28	275
1967	1,457	1,124	31	302
1968	1,586	1,203	35	348
1969	1,566	1,170	36	360
1970	1,562	1,127	35	400
1971	1,592	1,122	38	432
1972	1,629	1,142	41	445
1973	1,568	1,113	44	411
1974(est.)	1,486	1,046	44	396

[1] GNP implicit price deflators used to convert current dollars to constant 1967 dollars.

NOTE: Detail may not add to totals because of rounding.

SOURCE: National Science Foundation, *National Patterns of R&D Resources, 1953-75* (NSF 75-307).

Table 3-8. Estimated basic research expenditures in universities and colleges, by field of science, 1964-74
[Dollars in millions]

Field of science[1]	1964	1966	1968	1970	1972	1973	1974[2]
				Current dollars			
Total	$1,003	$1,303	$1,649	$1,796	$2,024	$2,058	$2,151
Engineering	128	185	223	230	265	273	252
Physical sciences	176	228	253	242	282	268	279
Astronomy	13	18	19	15	18	18	19
Chemistry	56	69	82	80	94	91	96
Physics	98	128	137	127	142	141	147
Other physical sciences	9	13	15	20	28	18	18
Environmental sciences	43	52	94	97	133	134	152
Mathematical sciences	23	28	40	51	54	53	57
Life sciences	534	670	804	928	969	1,010	1,092
Biological	238	315	370	414	414	462	482
Clinical medical	259	308	380	436	501	500	561
Other life sciences	36	48	54	78	56	48	47
Psychology	26	31	47	47	68	67	70
Social sciences	61	80	128	130	162	170	182
Other sciences	11	29	61	71	89	82	68
				Constant 1967 dollars[3]			
Total	$1,084	$1,345	$1,585	$1,562	$1,629	$1,568	$1,486
Engineering	138	191	214	200	213	208	174
Physical sciences	190	235	243	210	227	204	193
Astronomy	14	19	18	13	14	14	13
Chemistry	60	71	79	70	76	69	66
Physics	106	132	132	110	114	107	102
Other physical sciences	10	13	14	17	23	14	12
Environmental sciences	46	54	90	84	107	102	105
Mathematical sciences	25	29	38	44	43	40	39
Life sciences	577	691	773	807	780	770	755
Biological	257	325	356	360	333	352	333
Clinical medical	280	318	365	379	403	381	388
Other life sciences	39	50	52	68	45	37	32
Psychology	28	32	45	41	55	51	48
Social sciences	66	83	123	113	130	130	126
Other sciences	12	30	59	62	72	62	47

[1] See Table 3-8a for descriptions of these fields.
[2] Preliminary data.
[3] GNP implicit price deflators used to convert current dollars to constant 1967 dollars.

NOTE: Detail may not add to totals because of rounding.

SOURCE: National Science Foundation, special tabulations.

Table 3-8a. Fields and subfields of R&D expenditures at colleges and universities

Field of science	Illustrative subfields
Engineering	Aeronautical, agricultural, chemical, civil, electrical, industrial, mechanical, metallurgical, mining, nuclear, petroleum, bio-and-biomedical, energy, textile, architecture
Physical sciences	Astronomy: astrophysics, optical and radio, X-ray, Gamma-ray, neutrino
	Chemistry: inorganic, organo-metallic, organic, physical, analytical, pharmaceutical, polymer science (excludes biochemistry)

Table 3-8a. (Continued)

	Physics: acoustics, atomic and molecular, condensed matter, elementary particles, nuclear structure, optics, plasma
	Other physical sciences: multidisciplinary projects within physical sciences, and physical sciences disciplines not described above.
Environmental sciences	Atmospheric sciences: aeronomy, solar weather modification, meteorology, extra-terrestrial atmospheres
	Geological sciences: engineering geophysics, geology, geodesy, geomagnetism, hydrology, geochemistry, paleomagnetism, paleontology, physical geography, cartography, seismology, soil sciences
	Oceanography: chemical, geological, physical, marine geophysics, marine biology, biological oceanography
Mathematical sciences	Mathematics: algebra, analysis, applied mathematics, foundations and logic, geometry, numerical analysis, statistics, topology
	Computer sciences: design, development, and application of computer capabilities to data storage and manipulation, information science
Life sciences	Biological sciences: anatomy, biochemistry, biophysics, biogeography, ecology, embryology, entomology, genetics, immunology, microbiology, nutrition, parasitology, pathology, pharmacology, physical anthropology, physiology, botany, zoology
	Agricultural:[1] agricultural chemistry, agronomy, animal science, conservation, dairy science, plant science, range science, wildlife
	Clinical medical: anesthesiology, cardiology, endocrinology, gastroenterology, hematology, neurology, obstetrics, ophthamology, preventive medicine and community health, psychiatry, radiology, surgery, veterinary medicine, dentistry, pharmacy
	Other life sciences: multidisciplinary projects within life sciences
Psychology	Animal behavior, clinical, educational, experimental, human development and personality, social
Social sciences	Economics: econometrics, international, industrial, labor, agricultural, public finance and fiscal policy
	Political science: regional studies, comparative government, international relations, legal systems, political theory, public administration
	Sociology: comparative and historical, complex organizations, culture and social structure, demography, group interactions, social problems and welfare, theory
	Other social sciences: history, cultural anthropology, linguistics, socio-economic geography, research in education
Other sciences	Multidisciplinary and interdisciplinary research not classifiable under a single primary field.

[1] Included with biology prior to 1974.

SOURCE: National Science Foundation, *Expenditures for Scientific and Engineering Activities at Universities and Colleges, Fiscal Year 1973* (NSF 75-316).

Table 3-9. Estimated Federal basic research expenditures in universities and colleges, by field of science, 1964-74
[Dollars in millions]

Field of science[1]	1964	1966	1968	1970	1972	1973	1974[2]
				Current dollars			
Total	$767	$1,009	$1,251	$1,296	$1,419	$1,461	$1,514
Engineering	105	151	181	185	196	203	175
Physical sciences	164	209	223	226	232	222	229
Astronomy	13	17	18	14	14	13	14
Chemistry	50	60	70	69	73	70	75
Physics	95	122	122	126	125	124	128
Other physical sciences	6	10	13	17	21	14	13
Environmental sciences	39	47	71	76	99	102	112
Mathematical sciences	21	26	34	42	41	40	43
Life sciences	371	472	584	605	652	692	752
Biological	126	160	204	215	249	285	283
Clinical medical	218	279	345	352	372	377	433
Other life sciences	27	33	35	38	31	30	36
Psychology	24	30	39	41	54	53	56
Social sciences	37	53	82	82	91	99	105
Other sciences	5	21	37	41	54	49	42
				Constant 1967 dollars[3]			
Total	$829	$1,041	$1,203	$1,127	$1,142	$1,113	$1,046
Engineering	113	156	174	161	158	155	121
Physical sciences	177	216	214	197	187	169	158
Astronomy	14	18	17	12	11	10	10
Chemistry	54	62	67	60	59	53	52
Physics	103	126	117	110	101	94	88
Other physical sciences	6	10	12	15	17	11	9
Environmental sciences	42	49	68	66	80	78	77
Mathematical sciences	23	27	33	37	33	30	30
Life sciences	401	487	561	526	525	527	520
Biological	136	165	196	187	200	217	196
Clinical Medical	235	288	332	306	299	287	299
Other life sciences	29	34	34	33	25	23	25
Psychology	26	31	37	36	43	40	39
Social sciences	40	55	79	71	73	75	73
Other sciences	5	22	36	36	43	37	29

[1] See table 3-8a for descriptions of these fields.
[2] Preliminary data.
[3] GNP implicit price deflators used to convert current dollars to constant 1967 dollars.

NOTE: Detail may not add to totals because of rounding.

SOURCE: National Science Foundation, special tabulations.

Table 3-10. Federal obligations for basic research in universities and colleges, by selected supporting agencies and by selected fields, 1973-74
[Dollars in millions]

Field of science[1]		Six-agency total	Department of Agriculture	Department of Defense	Department of Health, Education, and Welfare	Atomic Energy Commission	NASA	National Science Foundation
		Current dollars						
All fields	1973	$903.5	$37.2	$105.0	$317.9	$59.9	$56.3	$327.2
	1974(est.) ..	1,035.0	36.1	110.1	412.9	60.6	61.3	354.0
Astronomy	1973	26.5	—	1.6	—	—	17.1	7.8
	1974(est.) ..	30.6	—	1.7	—	—	20.5	8.4
Life sciences	1973	369.8	26.2	8.3	263.5	11.1	3.5	57.2
	1974(est.) ..	454.6	25.2	8.9	349.6	11.2	3.3	56.4
Psychology	1973	29.3	—	5.3	14.3	—	0.3	9.4
	1974(est.) ..	33.9	—	4.9	18.5	—	0.5	10.0
Chemistry	1973	66.1	1.9	4.4	18.0	8.3	3.4	30.1
	1974(est.) ..	71.6	1.7	4.5	23.4	7.8	2.9	31.3
Physics	1973	109.1	—	13.3	—	34.7	9.4	51.7
	1974(est.) ..	114.6	—	13.9	.1	36.1	11.1	53.4
Environmental sciences	1973	93.4	.4	28.9	—	—	12.9	51.2
	1974(est.) ..	103.9	.5	30.1	—	—	13.3	60.0
Mathematical and computer sciences	1973	41.0	—	16.2	1.1	2.4	0.1	21.2
	1974(est.) ..	42.0	—	16.8	1.4	2.0	0.2	21.6
Engineering	1973	81.5	1.2	26.4	3.3	3.5	6.0	41.1
	1974(est.) ..	88.6	1.1	29.0	4.3	3.5	6.9	43.8
Social sciences	1973	45.7	7.5	.1	16.2	—	(4)	21.9
	1974(est.) ..	44.1	7.5	—	13.7	—	0.1	22.8
Other sciences[2]	1973	41.2	—	0.5	1.5	—	3.6	35.6
	1974(est.) ..	51.0	—	0.3	1.8	—	2.5	46.4
		Constant 1967 dollars[3]						
All fields	1973	$688.5	$28.3	$80.0	$242.2	$45.6	$42.9	$249.3
	1974(est.) ..	715.2	24.9	76.1	285.3	41.9	42.4	244.6
Astronomy	1973	20.2	—	1.2	—	—	13.0	5.9
	1974(est.) ..	21.1	—	1.2	—	—	14.2	5.8
Life sciences	1973	281.8	20.0	6.3	200.8	8.5	2.7	43.6
	1974(est.) ..	314.1	17.4	6.1	241.6	7.7	2.3	39.0
Psychology	1973	22.3	—	4.0	10.9	—	0.2	7.2
	1974(est.) ..	23.4	—	3.4	12.8	—	0.3	6.9
Chemistry	1973	50.4	1.4	3.4	13.7	6.3	2.6	22.9
	1974(est.) ..	49.5	1.2	3.1	16.2	5.4	2.0	21.6
Physics	1973	83.1	—	10.1	—	26.4	7.2	39.4
	1974(est) ..	79.2	—	9.6	0.1	24.9	7.7	36.9
Environmental sciences	1973	71.2	0.3	22.0	—	—	9.8	39.0
	1974(est.) ..	71.8	0.3	20.8	—	—	9.2	41.5
Mathematical and computer sciences	1973	31.2	—	12.3	0.8	1.8	0.1	16.2
	1974(est.) ..	29.0	—	11.6	1.0	1.4	0.1	14.9
Engineering	1973	62.1	0.9	20.1	2.5	2.7	4.6	31.3
	1974(est.) ..	61.2	0.8	20.8	3.0	2.4	4.8	30.3
Social sciences	1973	34.8	5.7	0.1	12.3	—	(4)	16.7
	1974(est.) ..	30.5	5.2	—	9.5	—	0.1	15.8
Other sciences[2]	1973	31.4	—	0.4	1.1	—	2.7	27.1
	1974(est.) ..	35.2	—	0.2	1.2	—	1.7	32.1

[1] See Appendix table 3-6a for descriptions of these fields.
[2] Including inter- and multi-disciplinary sciences.
[3] GNP implicit price deflators used to convert current dollars to constant 1967 dollars.
[4] Less than $50,000.

NOTE: Detail may not add to totals because of rounding.

SOURCE: National Science Foundation, special tabulations.

Table 3-11. Concentration of R&D expenditures at the 100 universities and colleges with the greatest expenditures in selected fields, 1974
[Dollars in millions]

Rank of institutions	Life sciences: Current dollars	Life sciences: Cumulative percent[1]	Physical sciences: Current dollars	Physical sciences: Cumulative percent[1]	Social sciences: Current dollars	Social sciences: Cumulative percent[1]	Engineering: Current dollars	Engineering: Cumulative percent[1]	Environmental sciences: Current dollars	Environmental sciences: Cumulative percent[1]
First 10	$ 354	22	$104	31	$ 75	30	$113	33	$108	47
First 20	605	37	160	47	116	47	164	47	146	63
First 30	790	49	197	58	142	58	203	59	169	73
First 40	931	58	226	67	161	66	234	68	183	79
First 50	1,049	65	250	74	176	72	259	75	194	84
First 60	1,153	71	266	78	187	76	278	80	203	88
First 70	1,242	77	279	82	196	80	293	85	209	91
First 80	1,316	81	289	85	204	83	304	88	214	93
First 90	1,378	85	297	88	210	86	314	91	217	94
First 100	1,431	89	304	90	215	88	322	93	220	95

[1] Based on total R&D expenditures in individual fields.

SOURCE: National Science Foundation, special tabulations.

Table 3-12. Basic research expenditures per scientist and engineer[1] in doctorate-granting institutions, by source, 1966-74

	1966	1968	1970	1972	1973	1974 (Prelim.)
	Basic research expenditures per scientist and engineer (in constant 1967 dollars[2])					
All sources	$11,500	$11,700	$10,300	$10,100	$9,500	$8,400
Federal	8,900	8,900	7,500	7,100	6,900	6,300
Non-Federal	2,600	2,800	2,900	3,000	2,700	2,100
	Basic research expenditures (in millions of constant 1967 dollars)					
All sources	$1,319	$1,555	$1,538	$1,598	$1,519	$1,372
Federal	1,021	1,178	1,110	1,123	1,096	1,034
Non-Federal	298	377	427	475	424	338
	Basic research expenditures (in millions of current dollars)					
All sources	$1,278	$1,617	$1,769	$1,986	$1,994	$1,986
Federal	989	1,225	1,277	1,396	1,438	1,497
Non-Federal	279	392	492	591	556	489
Scientists and engineers[1]	114,500[3]	132,800[3]	148,700[3]	158,500[3]	159,641	163,526

[1] Includes all scientists and engineers (full-time equivalent basis) employed in universities granting doctorate degrees in at least one field of science or engineering as of January.
[2] GNP implicit price deflators used to convert current dollars to constant 1967 dollars.
[3] Estimated.

NOTE: Detail may not add to totals because of rounding.

SOURCE: National Science Foundation, special tabulations.

Table 3-13. Estimated basic research expenditures in doctorate-granting institutions per scientist and engineer[1] by selected fields, 1966-74

Field of science	1966	1968	1970	1972	1973	1974 (Prelim.)
	Estimated constant 1967 dollars per scientist and engineer					
Physics	$24,500	$20,600	$16,600	$16,600	$15,300	$14,900
Biological sciences	10,900	10,600	10,100	9,600	10,400	9,700
Engineering	12,100	12,600	11,300	11,800	11,400	9,600
Chemistry	12,100	11,600	9,700	10,300	9,000	8,200
Clinical medicine	10,500	9.800	8,700	8,400	7,800	8,000
Psychology	7,400	8,200	6,600	7,900	6,800	6,100
Social sciences	4,800	6,000	4,900	5,000	4,800	4,600
Mathematical sciences	4,800	4,900	4,800	4,500	4,100	3,800
	Estimated constant 1967 dollars[2] (in millions)					
Physics	$132	$128	$108	$111	$104	$100
Biological sciences	323	346	353	328	347	325
Engineering	184	209	195	212	206	172
Chemistry	69	74	66	73	66	64
Clinical medicine	316	364	377	396	375	386
Psychology	28	41	39	52	48	46
Social sciences	75	118	109	123	120	117
Mathematical sciences	29	37	43	43	40	39
	Estimated current dollars (in millions)					
Physics	$128	$133	$124	$138	$137	$144
Biological sciences	313	360	406	407	455	470
Engineering	178	217	224	264	270	249
Chemistry	67	77	76	91	87	92
Clinical medicine	306	379	434	492	492	559
Psychology	27	43	45	65	63	66
Social sciences	73	123	125	153	157	169
Mathematical sciences	28	39	50	53	52	56
	Estimated scientists and engineers (as of January)					
Physics	5,400	6,200	6,500	6,700	6,800	6,700
Biological sciences	29,500	32,700	34,800	34,000	33,400	33,600
Engineering	15,200	16,600	17,200	17,900	18,000	18,000
Chemistry	5,700	6,400	6,800	7,100	7,300	7,800
Clinical medicine	30,200	37,000	43,200	47,400	48,300	48,100
Psychology	3,800	5,000	5,900	6,600	7,100	7,600
Social sciences	15,700	19,700	22,100	24,300	24,900	25,400
Mathematical sciences	6,100	7,600	8,900	9,600	9,700	10,400

[1] Includes all scientists and engineers (full-time equivalent basis) employed in universities granting doctorates in science or engineering. Estimates used for January 1966, 1968, 1970 and 1972.
[2] GNP implicit price deflators used to convert current dollars to constant 1967 dollars.

SOURCE: National Science Foundation, special tabulations.

Table 3-14. Basic research expenditures at Federally Funded Research and Development Centers administered by universities, by source, 1964-74
[Dollars in millions]

Year	All sources		Federal sources		Non-Federal	
	All R&D	Basic research	All R&D	Basic research	All R&D	Basic research
	Current dollars					
1964	$629.2	$191.0	$629.2	$191.0	([1])	([1])
1966	629.5	226.5	629.4	226.5	$0.1	([1])
1968	718.9	275.6	715.3	273.4	3.6	$2.2
1970	736.8	268.7	734.1	267.1	2.7	1.6
1972	763.6	250.2	758.3	248.0	5.3	2.2
1973	816.9	297.0	812.9	295.0	4.0	2.0
1974	865.0	290.9	861.2	288.9	3.8	2.0
	Constant 1967 dollars[2]					
1964	$679.7	$206.3	$679.7	$206.3	([1])	([1])
1966	649.6	233.7	649.5	233.7	$0.1	([1])
1968	691.2	265.0	687.7	262.9	3.5	$2.1
1970	640.6	233.6	638.3	232.2	2.3	1.4
1972	614.5	201.4	610.3	199.6	4.3	1.8
1973	622.5	226.3	619.4	224.8	3.0	1.5
1974	597.7	201.0	595.1	199.6	2.6	1.4

[1] Less than $50,000.
[2] GNP implicit price deflators used to convert dollars to constant 1967 dollars.

SOURCE: National Science Foundation, *National Patterns of R&D Resources, 1953-75* (NSF 75-307) and special tabulations.

Table 3-14a. Federally Funded Research and Development Centers

Name	Sponsoring agency	Organizational affiliation
	Administered by universities	
Ames Laboratory	Atomic Energy Commission	Iowa State University of Science and Technology
Applied Physics Laboratory	Department of the Navy	Johns Hopkins University
Applied Research Laboratory	Department of the Navy	Pennsylvania State University
Argonne National Laboratory	Atomic Energy Commission	University of Chicago and Argonne Universities Association
Brookhaven National Laboratory	Atomic Energy Commission	Associated Universities, Inc.
Cambridge Electron Accelerator	Atomic Energy Commission	Harvard University
Center for Naval Analysis	Department of the Navy	University of Rochester
Cerro Tololo Inter-American Observatory	National Science Foundation	Association of Universities for Research in Astronomy, Inc.
E.O. Lawrence Berkeley Laboratory	Atomic Energy Commission	University of California
E.O. Lawrence Livermore Laboratory	Atomic Energy Commission	University of California
Jet Propulsion Laboratory	National Aeronautics and Space Administration	California Institute of Technology
Kitt Peak National Observatory	National Science Foundation	Association of Universities for Research in Astronomy, Inc.
Lincoln Laboratory	Department of the Air Force	Massachusetts Institute of Technology
Los Alamos Scientific Laboratory	Atomic Energy Commission	University of California
Fermi National Accelerator Laboratory	Atomic Energy Commission	Universities Research Association, Inc.
National Astronomy and Ionosphere Center	National Science Foundation	Cornell University
National Center for Atmospheric Research	National Science Foundation	University Corporation for Atmospheric Research
National Radio Astronomy Observatory	National Science Foundation	Associated Universities, Inc.
Oak Ridge Associated Universities	Atomic Energy Commission	Oak Ridge Associated Universities
Plasma Physics Laboratory	Atomic Energy Commission	Princeton University
Space Radiation Effects Laboratory	National Aeronautics and Space Administration	College of William and Mary
Stanford Linear Accelerator Center	Atomic Energy Commission	Stanford University
	Administered by industrial firms	
Bettis Atomic Power Laboratory	Atomic Energy Commission	Westinghouse Electric Corporation
Hanford Engineering Development Laboratory	Atomic Energy Commission	Westinghouse-Hanford Corporation
Knolls Atomic Power Laboratory	Atomic Energy Commission	General Electric Company
Liquid Metal Engineering Center	Atomic Energy Commission	Rockwell International Corporation
Mound Laboratory	Atomic Energy Commission	Monsanto Research Corporation
National Reactor Testing Station	Atomic Energy Commission	Aerojet Nuclear Corporation
Oak Ridge National Laboratory	Atomic Energy Commission	Union Carbide Corporation
Sandia Laboratory	Atomic Energy Commission	Western Electric Company, Inc.-Sandia Corp.
Savannah River Laboratory	Atomic Energy Commission	E.I. du Pont de Nemours & Co., Inc.
	Administered by other nonprofit institutions	
Institute for Defense Analysis	Department of Defense	Institute for Defense Analysis
Research Analysis Corporation	Department of the Army	Research Analysis Corporation
Aerospace Corporation	Department of the Air Force	Aerospace Corporation
Analytic Services, Inc.	Department of the Air Force	Analytic Services, Inc.
MITRE Corporation	Department of the Air Force	MITRE Corporation
RAND Corporation	Department of the Air Force	RAND Corporation
Atomic Bomb Casualty Commission	Atomic Energy Commission	National Academy of Sciences
Pacific Northwest Laboratory	Atomic Energy Commission	Battelle Memorial Institute

SOURCE: National Science Foundation, *Federal Funds for Research, Development, and Other Scientific Activities, Fiscal Years 1973, 1974, and 1975.* Vol. XXIII (NSF 74-320).

Table 3-15. Federal obligations for intramural basic research, by selected agencies, 1960-74
[Dollars in millions]

Agency	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974 (est.)
	Current dollars														
Total	$160	$206	$251	$299	$363	$424	$444	$472	$502	$565	$646	$535	$607	$585	$635
Department of Defense	53	54	64	73	76	80	85	82	86	90	96	99	113	112	104
National Aeronautics and Space Administration[1]	27	49	63	84	127	158	155	163	179	202	239	172	202	189	222
Department of Agriculture	23	28	32	37	43	57	62	63	67	77	85	87	97	100	107
Department of Health, Education and Welfare	18	25	31	39	45	47	59	67	70	88	114	68	77	79	86
Department of the Interior	19	21	23	24	26	31	34	40	41	43	40	41	47	55	66
Department of Commerce	9	11	15	19	21	22	20	22	24	26	36	35	33	14	15
Other agencies	11	18	22	23	25	29	29	35	35	39	36	33	38	36	35
	Constant 1967 dollars[2]														
Total	$182	$231	$279	$328	$389	$446	$458	$472	$483	$518	$562	$445	$488	$446	$439
Department of Defense	60	62	72	80	82	85	88	82	83	83	83	82	91	85	72
National Aeronautics and Space Administration[1]	31	55	70	92	137	168	160	163	172	185	208	143	163	144	153
Department of Agriculture	26	31	36	41	46	60	64	63	64	71	74	72	78	76	74
Department of Health, Education and Welfare	20	28	34	43	49	50	61	67	67	81	99	57	62	60	59
Department of the Interior	22	24	26	26	28	33	35	40	39	39	35	34	38	42	46
Department of Commerce	10	12	17	21	23	23	21	22	23	24	31	29	27	11	10
Other Agencies	13	20	24	25	27	31	30	35	34	36	31	27	31	27	24

[1] The large amounts reported by NASA for basic research are due to the substantial cost of support equipment such as spacecraft and launch vehicles peculiar to space exploration, and the statistical prorations of costs for tracking and data acquisition.
[2] GNP implicit price deflators used to convert current dollars to constant 1967 dollars.

NOTE: Detail may not add to totals because of rounding.

SOURCE: National Science Foundation, *Federal Funds for Research, Development and other Scientific Activities, Fiscal Years 1973, 1974, and 1975.* Vol. XXIII (NSF 74-320-A), and earlier volumes.

Table 3-16. Industrial basic research expenditures, by source, 1960-74
[Dollars in millions]

Year	Total		Industry		Federal Government	
	Current dollars	Constant 1967 dollars[1]	Current dollars	Constant 1967 dollars[1]	Current dollars	Constant 1967 dollars[1]
1960	$376	$428	$297	$338	$ 79	$ 90
1961	395	444	314	353	81	91
1962	488	542	345	384	143	159
1963	522	573	375	411	147	161
1964	549	593	384	415	165	178
1965	592	628	406	431	186	197
1966	624	644	451	465	173	179
1967	629	629	427	427	202	202
1968	642	617	462	444	180	173
1969	618	567	458	420	160	147
1970	629	547	471	410	158	137
1971	610	507	485	403	125	104
1972	579	466	452	364	127	102
1973	605	461	473	360	132	101
1974(est.) .	640	442	500	345	140	97

[1] GNP implicit price deflators used to convert current dollars to constant 1967 dollars.

NOTE: Detail may not add to totals because of rounding.

SOURCE: National Science Foundation, *National Patterns of R&D Resources, 1953-75* (NSF 75-307).

Table 3-17. Expenditures for basic research in industry, by major performing industries, 1960-73
[Dollars in millions]

Year	All industries	Aircraft and missiles	Electrical equipment and com-munications	Machinery	Chemicals and allied products	All other industries
			Current dollars			
1960	$376	$62	$ 77	$22	$115	$100
1961	395	40	79	25	124	127
1962	488	55	125	27	136	145
1963	522	59	133	25	152	153
1964	549	68	134	26	153	168
1965	592	74	148	22	173	175
1966	624	74	122	26	176	226
1967	629	73	131	26	184	215
1968	642	71	134	31	201	205
1969	618	67	134	21	206	190
1970	629	63	144	20	230	172
1971	610	54	145	20	241	150
1972	579	61	154	23	206	135
1973	599	52	166	25	222	134
			Constant 1967 dollars[1]			
1960	$428	$71	$ 88	$25	$131	$114
1961	444	45	89	28	139	143
1962	542	61	139	30	151	161
1963	573	65	146	27	167	168
1964	593	73	145	28	165	181
1965	628	78	157	23	183	186
1966	644	76	126	27	182	233
1967	629	73	131	26	184	215
1968	617	68	129	30	193	197
1969	567	61	123	19	189	174
1970	547	55	125	17	200	150
1971	507	45	121	17	200	125
1972	466	49	124	19	166	109
1973	456	40	126	19	169	102

[1] GNP implicit price deflators used to convert current dollars to constant 1967 dollars.

NOTE: Detail may not add to totals because of rounding.

SOURCE: National Science Foundation, *Research and Development in Industry, 1973* (NSF 75-315).

Table 3-18. Expenditures for basic research in industry by selected fields, 1967-73
[Dollars in millions]

Selected fields[1]	1967	1968	1969	1970	1971	1972	1973
	Current dollars						
Engineering	$172	$181	$170	$170	$159	$182	$187
Chemistry	162	191	213	196	186	181	186
Physics and astronomy	146	126	111	107	101	94	93
Biological sciences	NA	50	58	71	77	60	67
Clinical medical sciences	NA	26	16	36	40	21	27
Mathematics	12	13	13	13	14	12	12
Environmental sciences	14	11	11	8	8	6	6
	Constant 1967 dollars[2]						
Engineering	$172	$174	$156	$148	$132	$146	$142
Chemistry	162	184	195	170	155	146	142
Physics and astronomy	146	121	102	93	84	76	71
Biological sciences	NA	48	53	62	64	48	51
Clinical medical sciences	NA	25	15	31	33	17	21
Mathematics	12	12	12	11	12	10	9
Environmental sciences	14	11	10	7	7	5	5

[1] See Appendix table 3-18a for descriptions of these fields.
[2] GNP implicit price deflators used to convert current dollars to constant 1967 dollars.

NOTE: Detail may not add to totals because of rounding.

SOURCE: National Science Foundation, *Research and Development in Industry 1973* (NSF 75-315).

Table 3-18a. Fields of industrial basic research expenditures

Field of science	Illustrative subfields
Engineering	Aeronautical, astronautical, chemical, civil, electrical, mechanical engineering, and metallurgy and materials.
Geological sciences	Geodesy, hydrology, geochemistry, seismology, and soil sciences.
Atmospheric sciences	Aeronomy, weather modification, and meteorology.
Clinical medical sciences	All sciences concerned with the use of scientific knowledge for the identification, treatment, and cure of disease. Includes internal medicine, neurology, preventive medicine and public health, psychiatry, dentistry, and pharmacy.
Biological sciences	All sciences which deal with life processes, including plant and animal sciences, bacteriology, pathology, microbiology, and pharmacology.
Other sciences	Multidisciplinary and interdisciplinary projects which cannot be classified within one of the above primary fields of science.

SOURCE: National Science Foundation, *Research and Development in Industry, 1973* (NSF 75-315).

Table 3-19. Basic research expenditures in nonprofit institutions,[1] by source, 1960-74
[Dollars in millions]

Year	Current dollars: Total	Current dollars: Federal Government	Current dollars: Industry	Current dollars: Own funds[3]	Constant 1967 dollars[2]: Total	Constant 1967 dollars[2]: Federal Government	Constant 1967 dollars[2]: Industry	Constant 1967 dollars[2]: Own funds[3]
1960	$117	$ 58	$10	$ 49	$133	$ 66	$11	$56
1961	126	57	11	58	142	64	12	65
1962	161	80	12	69	179	89	13	77
1963	180	95	14	71	197	104	15	78
1964	194	108	15	71	210	117	16	77
1965	210	120	16	74	223	127	17	78
1966	226	132	18	76	233	136	19	78
1967	221	125	19	77	221	125	19	77
1968	217	118	20	79	209	113	19	76
1969	213	111	22	80	195	102	20	73
1970	208	100	25	83	181	87	22	72
1971	225	110	25	90	187	92	21	75
1972	245	125	25	95	197	101	20	76
1973	255	130	30	95	194	99	23	72
1974(est.) .	274	144	30	100	189	100	21	69

[1] Includes State-administered hospitals.
[2] GNP inplicit deflators used to convert current dollars to constant 1967 dollars.
[3] Includes State and local government funds.

NOTE: Detail may not add to totals because of rounding.

SOURCE: National Science Foundation, *National Patterns of R&D Resources, 1953-75* (NSF 75-307).

Table 3-20. Relative growth in scientific research publications, by selected fields of science, 1960-73

Field of science	Percent growth after 1960: 1962	1964	1966	1968	1969	1970	1971	1972	1973
Astronomy	17	44	66	90	107	107	124	144	144
Atmospheric sciences	56	79	117	198	181	223	231	264	240
Biology	22	47	77	102	113	114	119	130	142
Chemistry	28	47	56	82	75	77	67	94	87
Engineering	7	39	56	72	74	90	94	92	79
Geology	7	15	24	32	43	39	55	50	69
Mathematics	22	42	84	117	159	162	162	195	193
Oceanography	19	21	49	76	116	91	84	100	75
Physics	36	47	72	109	108	97	99	98	93
Economics	—	—	5	15	33	26	26	25	25
Political science	—	3	8	31	58	53	44	50	53
Psychology	15	141	129	145	198	234	263	256	NA
Sociology	56	177	176	216	216	199	226	275	210

SOURCE: National Federation of Abstracting and Indexing Services, *Indicators of the Output of Scientific Research*, 1974 (A study commissioned specifically for this report and partially supported by the Office of Science Information Service of the National Science Foundation).

Table 3-21. Publication output for selected fields of science, percent of yearly totals by sectors, 1960-73

Field and sector	1960	1962	1964	1966	1968	1969	1970	1971	1972	1973
Astronomy										
Academic	71	79	80	74	76	79	84	84	82	79
Industry	5	—	3	6	4	5	3	4	5	4
Government	20	10	9	19	18	17	12	11	12	16
Nonprofit	2	4	3	2	3	—	—	—	1	1
Other	2	6	5	—	—	—	2	1	—	—
Atmospheric sciences										
Academic	56	53	53	50	53	52	60	57	56	58
Industry	6	9	13	20	12	12	9	7	11	10
Government	31	36	32	26	32	33	29	33	31	29
Nonprofit	8	3	2	4	1	1	1	2	3	3
Other	0	—	—	2	1	2	1	2	—	1
Biology										
Academic	70	78	73	73	79	75	80	78	79	81
Industry	5	3	3	5	4	3	3	3	3	2
Government	16	14	14	13	10	14	12	12	11	10
Nonprofit	7	4	8	7	6	7	5	6	6	7
Other	2	1	2	2	1	1	1	1	1	1
Chemistry										
Academic	59	61	62	60	70	68	68	69	77	75
Industry	25	30	29	26	21	24	23	22	17	18
Government	11	8	6	10	8	7	8	6	4	5
Nonprofit	3	1	2	4	1	1	1	2	1	(1)
Other	2	(1)	1	1	1	1	1	1	1	1
Economics										
Academic	72	75	70	83	87	82	92	81	88	78
Industry	7	9	14	6	6	—	1	7	3	5
Government	12	10	11	8	4	16	4	8	3	9
Nonprofit	3	—	—	—	—	—	—	—	—	1
Other	7	7	5	3	3	3	3	5	7	7
Engineering										
Academic	25	25	27	29	33	33	35	37	37	39
Industry	58	60	55	50	49	49	48	48	49	44
Government	12	14	16	17	15	16	14	13	13	14
Nonprofit	2	(1)	2	2	1	2	2	2	1	2
Other	3	2	1	2	1	1	1	1	1	1
Geology										
Academic	51	48	57	58	70	58	60	66	68	67
Industry	14	23	13	20	14	22	15	10	14	10
Government	18	18	20	15	10	14	16	17	11	18
Nonprofit	3	4	5	2	3	3	9	7	6	3
Other	15	8	6	5	2	4	1	1	2	2
Mathematics										
Academic	77	71	79	77	88	90	91	93	93	93
Industry	17	18	13	18	6	6	5	5	5	5
Government	4	5	1	2	4	1	3	2	2	2
Nonprofit	—	—	1	—	—	—	—	—	(1)	—
Other	2	7	7	3	1	3	(1)	(1)	(1)	(1)
Oceanography										
Academic	63	67	71	55	57	54	67	67	61	64
Industry	2	4	2	5	10	9	10	12	7	7
Government	33	22	21	26	25	30	19	13	24	21
Nonprofit	2	7	7	12	8	4	4	9	5	7
Other	—	1	—	2	—	1	1	—	2	1

(Continued)

Table 3-21 (Continued)

Physics										
Academic	50	57	62	62	66	70	68	66	61	72
Industry	28	29	27	29	23	19	19	17	20	16
Government	17	12	8	7	10	10	12	15	18	11
Nonprofit	4	2	2	3	1	—	(1)	1	—	—
Other	1	—	1	—	—	1	1	—	(1)	—
Political science										
Academic	81	85	84	85	89	90	93	83	82	91
Industry	—	—	5	3	4	4	2	6	4	2
Government	6	9	5	8	2	4	4	6	8	6
Nonprofit	8	—	5	5	—	2	—	2	2	—
Other	6	6	—	—	4	2	2	4	6	2
Psychology										
Academic	59	65	64	72	79	80	70	74	74	NA
Industry	4	3	1	1	1	2	2	3	3	NA
Government	7	12	6	7	7	7	6	5	5	NA
Nonprofit	9	7	9	12	5	7	16	11	12	NA
Other	21	14	19	8	8	5	6	7	7	NA
Sociology										
Academic	63	64	66	83	82	86	86	86	83	90
Industry	2	4	3	2	(1)	1	2	2	1	1
Government	4	7	6	2	4	3	4	3	4	3
Nonprofit	—	3	7	4	5	4	2	3	3	2
Other	31	22	19	9	8	6	6	7	9	3

[1] Less than 0.5 percent.

SOURCE: National Federation of Abstracting and Indexing Services, *Indicators of the Output of Scientific Research*, 1974 (A study commissioned specifically for this report and partially supported by the Office of Science Information Service of the National Science Foundation).

Table 3-22a. Index of research publications in universities and colleges, 1966-73

Field	1966	1968	1970	1972	1973
Biology	100	123	132	141	151
Chemistry	100	136	129	160	149
Engineering	100	127	147	157	158
Mathematics	100	135	168	193	191
Physics	100	129	125	114	131

SOURCE: National Federation of Abstracting and Indexing Services, *Indicators of the Output of Scientific Research*, 1974 (A study commissioned specifically for this report and partially supported by the Office of Science Information Service of the National Science Foundation).

Table 3-22b. Index of R&D expenditures in universities and colleges, 1964-72
(based on constant 1967 dollars[1])

Field	1964	1966	1968	1970	1971[2]
Biology	100	129	140	142	152
Chemistry	100	121	135	119	120
Engineering	100	154	173	162	162
Mathematics	100	125	159	182	173
Physics	100	128	130	111	107

[1] GNP implicit price deflators used to convert current dollars to constant 1967 dollars.
[2] Interpolated from 1970 and 1972 data.

SOURCE: National Science Foundation, *Expenditures for Scientific and Engineering Activities at Universities and Colleges, Fiscal Year 1973* (NSF 75-316-A).

Table 3-23. Citations per basic patent, by type of citation, 1950-61 and 1962-73

Type of citation	1950-61[1]	1962-73[2]
	Citations per basic patent	
All types	3.2	2.9
Basic research	0.6	0.7
Basic and/or applied research	1.2	1.3
Other patents	2.1	1.6
	Number of citations	
All types	148	135
Basic research	26	35
Basic and/or applied research	53	59
Other patents	95	76

[1] Based on 46 basic patents with citations.
[2] Based on 47 basic patents with citations.

SOURCE: Franklin Pierce College Law Center and the PTC Research Foundation, *Indicators of the Role of Science in Patented Technology*, 1974 (A study commissioned specifically for this report).

Table 3-24. Number and percent of basic patents citing research literature, by field of science and engineering, 1950-61 and 1962-73[1]

Field	1950-61		1962-73	
	Number[2]	Percent	Number[3]	Percent
Electrical engineering	7	32	9	31
Chemistry	7	32	8	28
Physics	2	9	9	31
Biology	5	23	2	7
Metallurgy	3	14	1	3
Mechanical engineering	2	9	2	7
Medicine	1	5	1	3

[1] A single patent may contain more than one citation, and these may be related to more than one field of science and engineering.
[2] Based on 22 basic patents with citations to basic or applied research.
[3] Based on 29 basic patents with citations to basic or applied research.

SOURCE: Franklin Pierce College Law Center and the PTC Research Foundation, *Indicators of the Role of Science in Patented Technology*, 1974 (A study commissioned specifically for this report).

Table 3-25. Number and percent of citations in basic patents to research literature and other patents, by source of citation, 1950-61 and 1962-73

Source of citation[1]	1950-61 Number	1950-61 Percent	1962-73 Number	1962-73 Percent
	All citations			
All sources	148	100	135	100
Government	8	5	19	14
Universities and nonprofit institutions	15	10	30	22
Corporations	120	81	79	59
Unidentified	5	3	7	5
	Basic research			
All sources	26	100	35	100
Government	1	4	8	23
Universities and nonprofit institutions	13	50	20	57
Corporations	9	35	3	9
Unidentified	3	12	4	11
	Basic and/or applied research			
All sources	53	100	59	100
Government	3	6	15	25
Universities and nonprofit institutions	15	28	28	48
Corporations	30	57	9	15
Unidentified	5	9	7	12
	Other patents			
All sources	95	100	76	100
Government	5	5	4	5
Universities and nonprofit institutions	—	—	2	3
Corporations	90	95	70	92
Unidentified	—	—	—	—

[1] Source is defined as the institution performing the cited research, or owning the cited patent.

SOURCE: Franklin Pierce College Law Center and the PTC Research Foundation, *Indicators of the Role of Science in Patented Technology*, 1974 (A study commissioned specifically for this report).

Table 4-1. Industrial R&D expenditures, 1960-74
(Dollars in billions)

Year	Current dollars	Constant 1967 dollars[1]
1960	$10.5	$12.0
1961	10.9	12.3
1962	11.5	12.7
1963	12.6	13.9
1964	13.5	14.6
1965	14.2	15.0
1966	15.5	16.0
1967	16.4	16.4
1968	17.4	16.8
1969	18.3	16.8
1970	18.1	15.7
1971	18.3	15.2
1972	19.4	15.6
1973	20.9	16.0
1974 (est)	22.0	15.2

[1] GNP implicit price deflators used to convert current dollars to constant 1967 dollars.

SOURCE: National Science Foundation, *National Patterns of R&D Resources, 1953-75,* (NSF 75-307).

Table 4-2. Expenditures for industrial R&D, advertising, and new plant and equipment, by manufacturing industries, 1960-73
(Current dollars in billions)

Year	Expenditures for industrial R&D		Expenditures for advertising	Expenditures for new plant and equipment
	All sources	Industry sources		
1960	$10.5	$4.4	$5.2	$10.1
1961	10.9	4.7	5.3	9.8
1962	11.5	5.0	5.6	10.4
1963	12.6	5.4	6.0	11.4
1964	13.5	5.8	6.6	13.3
1965	14.2	6.4	7.5	16.6
1966	15.5	7.2	8.1	20.2
1967	16.4	8.0	8.3	20.4
1968	17.4	8.9	8.7	20.6
1969	18.3	9.9	9.5	22.3
1970	18.1	10.3	9.5	22.2
1971	18.3	10.6	9.7	21.0
1972(est)	19.4	11.3	10.0	22.9
1973(est)	20.9	12.7	12.8	27.8

SOURCE: National Science Foundation, *National Patterns of R&D Resources, 1953-75* (NSF 75-307) and Department of Commerce, Bureau of the Census, *Statistical Abstracts of the U.S.,* 1960-74.

Table 4-3. Expenditures for industrial R&D, by source of funds, 1960-74

(Dollars in billions)

Year	Current dollars		Constant 1967 dollars[1]	
	Industry	Federal Government	Industry	Federal Government
1960	$4.4	$6.1	$5.0	$6.9
1961	4.7	6.2	5.2	7.0
1962	5.0	6.4	5.6	7.2
1963	5.4	7.3	5.9	8.0
1964	5.8	7.7	6.3	8.3
1965	6.4	7.7	6.8	8.2
1966	7.2	8.3	7.4	8.6
1967	8.0	8.4	8.0	8.4
1968	8.9	8.6	8.5	8.2
1969	9.9	8.5	9.0	7.8
1970	10.3	7.8	8.9	6.8
1971	10.6	7.7	8.9	6.4
1972	11.3	8.0	9.1	6.5
1973	12.7	8.3	9.7	6.3
1974(est)	13.7	8.3	9.2	5.7

[1] GNP implicit price deflators used to convert current dollars to constant 1967 dollars.

SOURCE: National Science Foundation, *National Patterns of R&D Resources, 1953-75* (NSF 75-307).

Table 4-4. Scientists and engineers[1] engaged in industrial R&D, by source of funds, 1960-74 (as of January of each year)

Year	Total	Industry	Federal Government
1960	292,000	163,400	128,600
1961	312,100	172,900	139,200
1962	312,000	172,800	139,200
1963	327,300	168,800	158,500
1964	340,200	174,700	165,500
1965	343,600	180,400	163,200
1966	353,200	190,100	163,100
1967	367,200	205,000	162,200
1968	376,700	218,200	158,500
1969	387,100	227,500	159,600
1970	384,100	232,500	151,600
1971	366,800	237,800	129,000
1972	350,100	232,000	118,100
1973	356,600	238,400	118,200
1974	360,600	249,600	111,000

[1] Full-time equivalent basis.

SOURCE: National Science Foundation, *Research and Development in Industry, 1973* (NSF 75-315).

Table 4-5. R&D expenditures, by industry, 1960-73

Industry	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
	Current dollars in millions													
Total	$10,509	$10,908	$11,464	$12,630	$13,512	$14,185	$15,548	$16,385	$17,429	$18,308	$18,062	$18,311	$19,383	$20,921
Food and kindred products	104	125	121	130	144	157	164	183	187	205	235	245	260	270
Textiles and apparel	38	30	28	30	32	38	51	57	58	60	58	59	61	64
Lumber, wood products, and furniture	10	10	10	11	12	11	12	12	19	15	48	48	51	55
Paper and allied products	56	59	65	69	77	94	117	128	144	188	178	187	186	198
Chemicals and allied products	980	1,101	1,175	1,239	1,284	1,356	1,407	1,507	1,588	1,659	1,766	1,819	1,896	2,081
Industrial chemicals	666	706	738	809	865	908	918	966	985	1,013	1,040	1,020	1,042	1,133
Drugs and medicines	162	180	195	216	234	267	308	343	393	434	464	510	547	618
Other chemicals	152	215	242	214	185	181	181	198	210	212	262	289	307	330
Petroleum refining and extraction	296	299	310	317	393	397	371	371	437	467	515	505	468	504
Rubber products	121	138	141	156	158	162	168	182	205	217	220	230	264	285
Stone, clay, and glass products	88	88	96	100	109	112	117	136	142	159	157	155	165	176
Primary metals	177	177	171	183	195	213	232	242	251	257	275	272	261	272
Ferrous metals and products	102	98	97	106	116	128	139	135	135	136	149	144	138	147
Nonferrous metals and products	75	79	74	77	79	85	93	107	115	121	126	128	122	125
Fabricated metal products	145	136	146	153	148	145	154	163	183	182	200	233	241	267
Machinery	949	901	914	958	1,015	1,065	1,217	1,326	1,477	1,536	1,649	1,773	1,960	2,144
Electrical equipment and communication	2,532	2,483	2,639	2,866	2,972	3,200	3,626	3,867	4,105	4,401	4,352	4,534	4,916	5,333
Radio and TV receiving equipment	(1)	(1)	(1)	(1)	(1)	(1)	47	45	55	57	70	64	48	51
Communication equipment and electronic components	1,324	1,404	1,591	1,773	1,872	1,989	2,249	2,425	2,538	2,713	2,736	2,881	3,159	3,420
Other electrical equipment	1,208	1,079	1,048	1,093	1,100	1,211	1,330	1,397	1,512	1,631	1,546	1,589	1,710	1,861
Motor vehicles and other transportation equipment	884	936	999	1,090	1,182	1,230	1,344	1,354	1,491	1,558	1,582	1,756	1,983	2,438
Aircraft and missiles	3,514	3,829	4,042	4,712	5,078	5,148	5,526	5,669	5,776	5,909	5,245	4,912	4,992	5,051
Professional and scientific instruments	329	297	309	284	331	403	468	542	660	734	745	744	817	914
Scientific and mechanical measuring instruments	160	119	101	70	74	80	87	104	112	109	118	110	124	118
Optical, surgical, photographic, and other instruments	169	178	208	214	257	323	381	438	548	625	627	633	694	796
Other manufacturing industries	119	105	65	54	65	71	77	90	102	107	132	136	150	157
Nonmanufacturing industries	168	194	234	276	319	384	497	559	603	655	705	704	707	714

(Continued)

Table 4-5 (Continued)

Constant 1967 dollars in millions[2]

Industry	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
Total	$11,964	$12,260	$12,743	$13,858	$14,597	$15,046	$16,045	$16,385	$16,757	$16,793	$15,705	$15,233	$15,599	$15,942
Food and kindred products	118	141	135	143	156	167	169	183	180	188	204	204	209	206
Textiles and apparel	43	34	31	33	35	40	53	57	56	55	50	49	49	49
Lumber, wood products, and furniture	11	11	11	12	13	12	12	12	18	14	42	40	41	42
Paper and allied products	64	66	72	76	83	100	121	128	138	172	155	156	150	151
Chemicals and allied products	1,116	1,238	1,306	1,359	1,387	1,438	1,452	1,507	1,527	1,522	1,536	1,513	1,526	1,586
Industrial chemicals	758	794	820	888	934	963	947	966	947	929	904	849	839	863
Drugs and medicines	184	202	217	237	253	283	318	343	378	398	403	424	440	471
Other chemicals	173	242	269	235	200	192	187	198	202	195	228	240	247	251
Petroleum refining and extraction	337	336	345	348	425	421	383	371	420	428	448	420	377	384
Rubber products	138	155	157	171	171	172	173	182	197	199	191	191	212	217
Stone, clay, and glass products	100	99	107	110	118	119	121	136	137	146	137	129	133	134
Primary metals	202	199	190	201	211	226	239	242	241	236	239	226	210	207
Ferrous metals and products	116	110	108	116	125	136	143	135	130	125	130	120	111	112
Nonferrous metals and products	85	89	82	85	85	90	96	107	111	111	110	107	98	95
Fabricated metal products	165	153	162	168	160	154	159	163	176	167	174	194	194	203
Machinery	1,080	1,013	1,016	1,051	1,097	1,130	1,256	1,326	1,420	1,409	1,434	1,475	1,577	1,634
Electrical equipment and communication	2,883	2,791	2,934	3,145	3,211	3,394	3,742	3,867	3,947	4,037	3,784	3,772	3,956	4,064
Radio and TV receiving equipment	(1)	(1)	(1)	(1)	(1)	(1)	49	45	53	52	61	53	39	39
Communication equipment and electronic components	1,507	1,578	1,769	1,945	2,022	2,110	2,321	2,425	2,440	2,489	2,379	2,397	2,542	2,606
Other electrical equipment	1,375	1,213	1,165	1,199	1,188	1,285	1,373	1,397	1,454	1,496	1,344	1,322	1,376	1,418
Motor vehicles and other transportation equipment	1,006	1,052	1,111	1,196	1,277	1,305	1,387	1,354	1,434	1,429	1,376	1,461	1,596	1,858
Aircraft and missiles	4,001	4,304	4,493	5,170	5,486	5,460	5,703	5,669	5,553	5,420	4,561	4,086	4,017	3,849
Professional and scientific instruments	375	334	344	312	358	428	483	542	637	673	648	619	657	696
Scientific and mechanical measuring instruments	182	134	112	77	80	85	90	104	108	100	103	92	100	90
Optical, surgical, photographic, and other instruments	192	200	231	235	278	343	393	438	527	573	545	527	559	607
Other manufacturing industries	136	118	72	59	70	75	80	90	98	98	115	113	121	120
Nonmanufacturing industries	191	218	260	303	345	407	513	559	580	601	613	586	569	544

[1] Included in the other electrical equipment group.
[2] GNP implicit price deflators used to convert current dollars to constant 1967 dollars.

SOURCE: National Science Foundation, *Research and Development in Industry, 1973* (NSF 75-315).

Table 4-6. Industrial R&D expenditures, percent change, 1971-73

Industry	Percent change: Current dollars	Percent change: Constant 1967 dollars[1]
Motor vehicles and other transportation equipment	38.8	27.2
Rubber products	23.9	13.6
Professional and scientific instruments	22.9	12.4
Machinery	20.9	10.8
Electrical equipment and communication	17.6	7.7
Fabricated metal products	14.6	4.6
Lumber, wood products, and furniture	14.6	5.0
Chemicals and allied products	14.4	4.8
Stone, clay, and glass products	13.6	3.9
Food and kindred products	10.2	1.0
Textiles and apparel	8.5	0.0
Paper and allied products	5.9	-3.2
Aircraft and missiles	2.9	-5.8

[1] GNP implicit price deflators used to convert current dollars to constant 1967 dollars.

SOURCE: National Science Foundation, *Research and Development in Industry, 1973*, (NSF 75-315).

Table 4-7. Industrial R&D expenditures for basic research, applied research, and development, 1960-74

(Dollars in millions)

Year	Total	Basic research	Applied research	Development
	Current dollars			
1960	$10,509	$376	$2,029	$8,104
1961	10,908	395	1,977	8,536
1962	11,464	488	2,449	8,527
1963	12,630	522	2,457	9,651
1964	13,512	549	2,600	10,363
1965	14,185	592	2,658	10,935
1966	15,548	624	2,843	12,081
1967	16,385	629	2,915	12,841
1968	17,429	642	3,124	13,663
1969	18,308	618	3,287	14,403
1970	18,062	629	3,399	14,034
1971	18,311	610	3,384	14,317
1972	19,371	579	3,473	15,319
1973	20,937	605	3,759	16,573
1974(est.)	22,026	640	4,025	17,355
	Constant 1967 dollars[1]			
1960	$11,964	$428	$2,310	$9,226
1961	12,260	444	2,222	9,594
1962	12,743	542	2,722	9,478
1963	13,857	572	2,695	10,589
1964	14,596	593	2,809	11,195
1965	15,045	628	2,819	11,598
1966	16,045	644	2,934	12,467
1967	16,385	629	2,915	12,841
1968	16,803	617	3,003	13,136
1969	16,793	567	3,015	13,211
1970	15,704	547	2,955	12,202
1971	15,233	507	2,815	11,910
1972	15,589	466	2,795	12,328
1973	15,954	461	2,864	12,629
1974(est.)	15,220	442	2,781	11,992

[1] GNP implicit price deflators used to convert current dollars to constant 1967 dollars.

SOURCE: National Science Foundation, *National Patterns of R&D Resources 1953-75* (NSF 75-307).

Table 4-8. Percent distribution of industrial R&D expenditures among selected industries, 1960-73

Industry	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
Five industry total	84	85	85	86	85	85	84	84	83	82	81	81	81	82
Aircraft and missiles	33	35	35	37	38	36	36	35	33	32	29	27	26	24
Electrical equipment and communication	24	23	23	23	22	23	23	24	24	24	24	25	25	26
Chemicals and allied products	9	10	10	10	10	10	9	9	9	9	10	10	10	10
Motor vehicles and other transportation equipment	8	9	9	9	9	9	9	8	9	9	9	10	10	12
Machinery	9	8	8	8	8	8	8	8	9	8	9	10	10	10

SOURCE: National Science Foundation, *Research and Development in Industry, 1973* (NSF 75-315)

Table 4-9a. Percent distribution of scientists and engineers[1] engaged in industrial R&D, for selected industries, January, 1961-74

Industry	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Five industry total	79	80	82	81	81	80	80	79	79	78	77	79	78	77
Aircraft and missiles	25	26	28	30	29	28	27	27	26	24	21	20	20	20
Electrical equipment and communication	25	26	26	26	26	26	27	26	26	27	26	25	26	26
Chemicals and allied products	12	12	12	11	11	11	10	10	10	10	12	13	11	12
Machinery	11	10	10	8	9	9	9	10	10	11	11	12	12	12
Motor vehicles and other transportation equipment	6	7	6	7	7	7	7	6	7	7	8	8	8	8

[1] Full-time equivalent basis.

SOURCE: National Science Foundation, *Research and Development in Industry, 1973,* (NSF 75-315).

Table 4-9b. Scientists and engineers[1] engaged in industrial R&D, January, 1961-74
(In thousands)

Industry	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
	January													
Total	312.1	312.0	327.3	340.2	343.6	353.2	367.2	376.7	387.1	384.1	366.8	349.9	356.6	360.6
Food and kindred products	5.2	5.4	5.1	5.7	6.2	6.2	6.1	6.3	6.3	6.3	6.7	6.6	6.7	6.8
Textiles and apparel	1.1	([2])	1.0	1.2	1.2	1.4	1.9	2.5	2.6	2.9	1.8	1.8	1.9	1.8
Lumber, wood products and furniture	0.5	0.6	0.5	0.5	0.5	0.6	0.5	0.5	0.9	1.0	1.7	1.7	1.6	1.6
Paper and allied products	2.6	2.6	2.5	3.8	3.8	4.3	4.7	4.8	4.8	4.9	5.0	4.9	4.9	5.1
Chemicals and allied products	37.0	36.5	38.3	35.8	37.9	38.0	36.9	38.9	40.3	40.2	42.8	40.9	40.7	42.3
Industrial chemicals	22.9	21.6	22.9	22.2	24.3	23.3	21.7	22.3	22.6	21.9	22.4	19.7	19.8	20.5
Drugs and medicines	6.2	6.8	6.9	6.9	7.2	7.5	8.7	9.8	10.1	11.4	11.6	11.8	11.2	12.0
Other chemicals	7.9	8.1	8.5	6.7	6.4	7.2	6.5	6.8	7.6	6.9	8.8	9.5	9.7	9.8
Petroleum refining and extraction	9.0	9.1	8.9	8.1	8.7	8.9	8.7	9.2	10.0	9.9	9.2	8.3	8.2	8.3
Rubber products	5.5	5.6	5.8	6.0	5.8	5.7	5.8	6.1	6.3	6.8	5.9	5.8	5.8	5.7
Stone, clay, and glass products	3.6	3.7	3.8	3.3	3.5	3.1	3.3	4.1	4.2	4.6	4.1	3.9	3.9	4.2
Primary metals	6.9	6.0	5.2	5.1	5.5	5.5	5.9	5.9	6.2	6.3	6.3	6.0	5.5	5.6
Ferrous metals and products[2]	3.9	3.0	2.9	2.8	3.2	3.2	3.3	3.1	3.2	3.2	3.4	3.4	3.1	3.2
Nonferrous metals and products	3.0	3.0	2.3	2.3	2.3	2.3	2.5	2.7	3.0	3.1	2.9	2.6	2.4	2.4
Fabricated metal products[2]	8.6	7.4	6.8	7.0	6.6	6.3	6.3	5.6	6.6	5.9	6.9	6.4	6.5	6.9
Machinery	33.0	31.5	31.4	27.3	29.4	30.5	33.6	37.4	39.4	41.4	40.5	41.1	41.7	43.3
Electrical equipment and communication	79.2	82.3	85.8	89.5	87.8	92.0	98.6	98.4	101.6	102.4	95.2	87.7	92.6	94.7
Radio and TV receiving equipment	([2])	([2])	([2])	([2])	([2])	([2])	0.9	1.0	1.2	1.9	2.4	2.1	1.4	1.3
Communication equipment & electronic components	47.5	52.6	55.1	60.4	58.8	62.3	66.7	67.4	67.4	66.3	63.6	57.2	61.5	63.2
Other electrical equipment	31.7	29.7	30.7	29.1	29.0	29.7	31.0	30.0	33.0	34.2	29.4	28.4	29.7	30.2
Motor vehicles and other transportation equipment	19.1	20.8	21.1	23.3	24.1	24.8	25.2	24.3	25.0	25.1	27.8	29.3	29.2	28.5
Aircraft and missiles	78.5	79.4	90.7	101.1	99.2	99.3	100.4	101.1	99.9	92.6	78.3	71.2	72.3	70.3
Professional and scientific instruments	11.1	9.8	9.4	10.8	11.5	12.5	13.0	14.1	15.1	14.8	15.1	15.1	15.9	16.9
Scientific and mechanical measuring instruments	5.7	4.8	3.9	3.8	3.6	3.8	3.6	3.8	3.9	3.7	4.2	4.1	4.3	4.4
Optical, surgical, photographic, and other instruments	5.4	5.0	5.5	7.0	7.9	8.7	9.4	10.3	11.2	11.1	10.9	10.9	11.6	12.5
Other manufacturing industries	3.5	3.1	2.8	2.0	2.4	2.3	2.2	2.4	2.8	2.7	3.9	3.7	3.9	4.0
Nonmanufacturing industries	7.5	7.0	8.2	9.8	9.6	11.7	14.1	15.1	15.1	16.3	15.6	15.7	15.3	14.6

[1] Full-time equivalent basis.
[2] Not separately available but included in total.
[3] Data included in the other manufacturing industries group.

SOURCE: National Science Foundation, *Research and Development in Industry, 1973* (NSF 75-315).

Table 4-10. R&D intensity of U.S. manufacturing industries, 1961-72

Industry groups	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972
	Total R&D as a percent of net sales											
Group I	9.4	9.2	10.0	10.1	9.4	8.8	8.7	8.1	7.9	7.1	6.9	6.8
Group II	2.1	2.1	2.1	2.2	2.0	1.9	1.9	1.8	1.8	1.9	1.8	1.8
Group III	0.6	0.6	0.6	0.6	0.6	0.6	0.7	0.6	0.7	0.7	0.6	0.6
	Company funds for R&D as a percent of net sales											
Group I	3.2	3.2	3.4	3.4	3.5	3.4	3.6	3.5	3.7	3.5	3.5	3.4
Group II	1.7	1.6	1.6	1.7	1.6	1.6	1.5	1.5	1.6	1.7	1.6	1.6
Group III	0.4	0.5	0.4	0.5	0.5	0.4	0.6	0.4	0.4	0.5	0.4	0.4
	R&D scientists and engineers per 1,000 employees											
Group I	53.0	49.8	54.0	54.6	52.6	46.2	46.0	44.7	43.8	44.0	43.1	40.4
Group II	17.1	17.6	17.0	17.1	16.7	15.9	15.8	15.5	15.9	15.7	16.7	16.5
Group III	6.4	5.8	5.4	5.9	6.0	5.9	6.2	6.3	6.2	5.8	6.2	6.0

SOURCE: National Science Foundation, *Research and Development in Industry, 1973,* (NSF 75-315).

Table 4-11. U.S. patents granted for inventions, 1960-73

Year	All patents	U.S. residents				Foreign residents
		Total	U.S. corporations	U.S. individuals	U.S. Government	
1960	47,170	40,472	28,187	11,041	1,244	7,698
1961	48,368	40,154	28,351	10,330	1,473	8,214
1962	55,691	45,579	32,560	11,738	1,281	10,112
1963	45,679	37,174	26,632	9,521	1,021	8,505
1964	47,376	38,410	27,836	9,392	1,182	8,966
1965	62,857	50,332	37,158	11,634	1,540	12,525
1966	68,406	54,634	41,634	11,468	1,532	13,772
1967	65,652	51,274	38,353	11,164	1,757	14,378
1968	59,102	45,782	34,886	9,407	1,489	13,320
1969	67,557	50,395	38,847	9,798	1,750	17,162
1970	64,427	47,073	36,896	8,451	1,726	17,354
1971	78,316	55,988	43,022	11,019	1,947	22,328
1972	74,808	51,515	38,890	10,981	1,644	23,293
1973	74,139	51,501	38,615	11,073	1,813	22,638

SOURCE: Department of Commerce, *Statistical Abstracts of the U.S., 1960-74.*

Table 4-12. U.S. patents granted for inventions,[1] by selected major product field, 1963-73

Product Field	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973 (est.)
Food and kindred products	675	657	743	916	748	719	802	714	908	963	774
Textile mill products	882	786	884	1,112	1,026	953	1,129	1,070	1,275	1,267	914
Chemicals, except drugs and medicines	6,310	6,374	7,871	10,551	9,953	8,482	9,672	8,374	8,079	10,736	7,872
Basic industrial inorganic and organic chemicals	4,147	4,317	5,134	6,600	6,365	5,541	6,176	5,258	4,880	6,535	4,676
Plastics materials and synthetic resins	2,049	2,019	2,883	4,113	3,732	3,112	3,507	2,814	2,523	3,401	2,382
Agricultural chemicals	926	1,030	972	1,388	1,235	832	1,443	1,454	1,425	2,077	1,598
All other chemicals	1,605	1,560	1,920	2,523	2,414	1,953	2,166	1,990	2,205	2,648	2,062
Drugs and medicines	1,201	1,427	1,401	1,915	1,810	1,212	1,793	1,700	1,568	2,281	1,696
Petroleum and natural gas extraction and petroleum refining	852	890	1,157	1,324	1,195	1,083	1,113	1,074	1,073	1,148	912
Rubber and miscellaneous plastics products	4,318	4,331	5,606	6,403	6,190	5,483	6,219	5,422	6,129	6,096	4,976
Stone, clay, glass and concrete products	2,420	2,394	3,277	3,961	3,666	3,234	3,859	3,474	3,921	3,863	3,210
Primary metals	976	1,049	1,293	1,366	1,353	1,149	1,163	1,136	1,330	1,251	1,154
Primary ferrous products	816	843	1,069	1,129	1,159	963	954	969	1,101	1,018	982
Primary and secondary nonferrous metals	561	674	789	856	834	758	773	715	856	861	734
Fabricated metal products	9,613	9,988	13,151	13,739	12,833	11,205	12,045	10,453	12,252	11,283	10,650
Machinery, except electrical	17,096	17,756	22,974	23,988	21,651	19,420	20,647	18,560	22,752	19,636	19,206
Engines and turbines	1,373	1,432	1,768	1,656	1,397	1,336	1,262	1,154	1,399	1,171	1,226
Farm and garden machinery and equipment	2,147	2,276	2,875	2,741	2,435	2,173	2,314	2,093	2,571	2,157	2,152
Construction, mining and material handling machinery and equipment	3,710	3,761	5,124	4,885	4,545	3,805	4,018	3,485	4,426	3,596	3,814
Metalworking machinery and equipment	1,925	2,170	2,642	2,547	2,315	1,967	2,328	1,909	2,513	2,041	1,976
Office, computing and accounting machines	2,071	2,325	2,992	3,367	2,907	2,352	2,830	2,615	3,235	2,940	2,616
Other machinery, except electrical	11,936	12,470	15,906	17,122	14,995	13,949	14,344	12,676	15,546	13,424	13,068

(Continued)

Table 4-12 (Continued)

Electrical equipment, except communication equipment	6,720	7,240	10,334	11,322	10,093	8,724	9,601	9,042	10,481	8,692	8,512
Electrical transmission and distribution equipment	2,186	2,552	4,071	4,259	3,756	3,099	3,539	3,367	3,926	3,084	3,174
Electrical industrial apparatus	2,369	2,428	3,701	4,141	3,616	3,128	3,550	3,345	3,665	3,031	2,870
Other electrical machinery equipment and supplies	4,023	4,239	5,739	6,295	5,618	4,825	5,166	4,801	5,461	4,638	4,420
Communication equipment and electronic components	5,383	5,953	8,636	9,752	8,360	7,530	8,964	8,755	10,301	8,458	8,502
Radio and television receiving equipment, except communication types	953	1,026	1,632	1,753	1,425	1,438	1,730	1,714	2,091	1,610	1,524
Electronic components and accessories and communication equipment	5,315	5,888	8,527	9,623	8,264	7,414	8,874	8,687	10,215	8,379	8,412
Motor vehicles and other transportation equipment, except aircraft	3,641	3,729	4,804	4,452	4,125	3,895	3,899	3,457	4,206	3,641	4,262
Motor vehicles and motor vehicle equipment	1,991	1,970	2,695	2,438	2,315	2,214	2,186	1,930	2,320	2,040	2,246
Guided missiles and space vehicles and parts	617	672	817	805	654	612	576	513	537	441	510
Other transportation equipment	1,494	1,543	2,027	1,864	1,730	1,626	1,625	1,523	1,833	1,547	1,758
Ordnance, except missiles	450	494	562	486	460	449	434	350	523	473	776
Aircraft and parts	1,083	1,085	1,323	1,248	1,048	1,018	1,023	930	1,220	997	976
Professional and scientific instruments	5,754	5,856	7,766	8,657	7,401	7,028	8,409	8,395	9,854	8,543	8,236

[1] Patents originating in the United States.

SOURCE: Office of Technology Assessment and Forecast, U.S. Patent Office, *Indicators of the Patent Output of U.S. Industry*, 1974. (A study commissioned specifically for this report).

Table 4-13. U.S. patents granted for inventions in major product fields, by groups of R&D-intensive industries, 1963-73

R&D intensity	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
	Percent distribution										
Group I	66	67	67	68	67	67	67	68	68	68	68
Group II	30	30	30	29	30	30	29	28	28	28	28
Group III	4	4	3	3	4	4	4	4	4	4	4
	Number of patents										
Group I	31,250	32,854	43,719	48,148	45,595	40,862	47,340	45,749	55,530	52,576	52,646
Group II	14,343	14,580	19,409	20,489	20,136	18,372	20,298	18,621	22,717	21,777	21,505
Group III	1,900	1,872	2,287	2,489	2,525	2,212	2,599	2,545	3,175	3,267	2,852

NOTE: Detail may not add to totals because of rounding.

SOURCE: Office of Technology Assessment and Forecast, U.S. Patent Office, special tabulations.

Table 4-14. Distribution of major U.S. innovations, by size of company, 1953-73

Period	Total	Size of company: Less than 100 employees	100-999 employees	1,000-4,999 employees	5,000-9,999 employees	10,000 or more employees
	Percent distribution					
1953-73	100	19	23	14	6	38
1953-59	100	20	24	14	9	32
1960-66	100	22	23	14	5	37
1967-73	100	18	21	13	3	45
	Number of innovations					
1953-73	277	54	63	38	16	106
1953-59	90	18	22	13	8	29
1960-66	93	20	21	13	5	34
1967-73	94	16	20	12	3	43

NOTE: Detail may not add to totals because of rounding.

SOURCE: Gellman Research Associates, Inc., *Indicators of International Trends in Technological Innovation* 1975. (A study commissioned specifically for this report).

Table 4-15. Major U.S. innovations per $10 billion in sales, by size of company, 1953-73

Period	Size of company: Less than 100 employees	100-999 employees	1,000-4,999 employees	5,000-9,999 employees	10,000 or more employees
	Innovations per $10 billion in sales[1]				
1953-59	3.1	3.2	2.7	2.5	2.3
1960-66	3.0	2.6	2.1	1.3	1.9
1967-73	2.0	2.0	1.6	.6	1.6
Year[2]	Sales and receipts of U.S. manufacturing industries (dollars in millions)				
1958	$57,930.0	$68,996.1	$48,770.6	$31,756.5	$124,380.1
1963	67,760.1	82,332.5	63,146.9	37,888.2	179,990.6
1967	78,830.4	99,451.5	75,464.5	47,917.1	275,193.2

[1] The number of innovations can be found in Appendix table 4-14.
[2] Data on sales and receipts of U.S. manufacturing industries by company size are available only for years 1958, 1963, and 1967.

SOURCE: Gellman Research Associates, Inc., *Indicators of International Trends in Technological Innovation*, 1975. (A study commissioned specifically for this report), and Department of Commerce, Bureau of the Census, *Enterprise Statistics*, 1963 and 1967.

Table 4-16. Distribution of major U.S. innovations, by groups of R&D-intensive industries, 1953-73

Period	Total innovations	R&D intensity: Group I	Group II	Group III
	Percent distribution			
1953-73	100	66	24	10
1953-56	100	52	32	16
1957-60	100	67	17	17
1961-64	100	71	24	5
1965-68	100	78	15	7
1969-73	100	66	25	9
	Number of major innovations			
1953-73	277	182	66	29
1953-56	69	36	22	11
1957-60	36	24	6	6
1961-64	58	41	14	3
1965-68	46	36	7	3
1969-73	68	45	17	6

NOTE: Detail may not add to totals because of rounding.

SOURCE: Gellman Research Associates, Inc., *Indicators of International Trends in Technological Innovation*, 1975. (A study commissioned specifically for this report).

Table 4-17. Major U.S. innovations in selected industries, 1953-73

Industry	Number of innovations
Electrical equipment and communication .	53
Chemicals and allied products	45
Machinery	44
Professional and scientific instruments ...	29
Stone, clay, and glass products	18
Motor vehicles and other transportation equipment	18
Primary metals	17
Rubber products	15
Aircraft and missiles	11
Fabricated metal products	10
Petroleum refining and extraction	5
Textiles and apparel	4
Paper and allied products	4
Food and kindred products	2
Lumber, wood products, and furniture ...	2

SOURCE: Gellman Research Associates, Inc., *Indicators of International Trends in Technological Innovation*, 1975. (A study commissioned specifically for this report).

Table 4-18. "IR-100" award-wining innovations, by groups of R&D-intensive industries, 1963-74

Industry	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1963-74
	Percent												
Total	100	100	100	100	100	100	100	100	100	100	100	100	100
Group I total	63.0	68.0	69.0	65.0	62.0	65.0	58.0	59.8	64.7	53.9	55.9	58.4	61.9
Chemicals & allied products	13.5	10.1	7.3	10.5	7.8	13.0	13.3	15.2	11.8	16.7	8.1	13.9	11.7
Machinery	5.4	10.1	7.3	5.3	5.2	5.2	8.0	8.9	5.3	8.3	9.5	5.6	7.0
Electrical equipment & communications	43.2	36.7	32.9	43.4	44.2	48.1	36.0	30.4	42.1	25.0	29.7	33.3	37.1
Aircraft & missiles	5.4	2.5	4.9	7.9	6.5	3.9	1.3	2.5	2.6	—	1.4	1.4	3.4
Professional & scientific instruments	17.6	26.6	31.7	18.4	16.9	14.3	18.7	20.3	25.0	26.4	28.4	27.8	22.7
Group II total	8.0	7.0	9.0	9.0	12.0	10.0	15.0	13.7	7.8	11.8	9.8	8.9	10.2
Petroleum refining & extraction	2.7	—	—	—	1.3	1.3	1.3	3.8	1.3	2.8	4.1	—	1.5
Rubber products	—	—	—	—	2.6	1.3	1.3	2.5	—	—	1.4	1.4	0.9
Stone, clay, glass & concrete products	5.4	6.3	4.9	5.3	5.2	2.6	6.7	6.3	5.3	9.7	5.4	6.9	5.8
Fabricated metal products	—	1.3	—	—	2.6	2.6	1.3	1.3	1.3	—	1.4	1.4	1.1
Motor vehicles & other transportation equipment	2.7	1.3	6.1	6.6	3.9	5.2	9.3	3.8	2.6	4.2	1.4	2.8	4.2
Group III total	3.0	4.0	4.0	2.0	3.0	2.0	2.0	3.9	2.0	4.9	6.9	4.0	3.5
Food & kindred products	—	2.5	—	—	1.3	—	1.3	—	—	—	—	—	0.4
Textiles & apparel	—	—	1.2	—	—	—	—	—	—	1.4	1.4	—	0.3
Lumber, wood products & furniture	—	—	—	—	—	—	—	—	—	—	—	—	—
Paper & allied products	1.4	—	1.2	—	1.3	1.3	—	3.8	1.3	4.2	5.4	2.8	1.9
Primary metals	2.7	2.5	2.4	2.6	1.3	1.3	1.3	1.3	1.3	1.4	2.7	2.8	2.0
	Number of awards												
Total	100	100	100	100	100	100	100	102	102	102	102	101	1,209
Group I total	63	68	69	65	62	65	58	61	66	55	57	59	748
Chemicals & allied products	10	8	6	8	6	10	10	12	9	12	6	10	107
Machinery	4	8	6	4	4	4	6	7	4	6	7	4	64
Electrical equipment & communications	32	29	27	33	34	37	27	24	32	18	22	24	339
Aircraft & missiles	4	2	4	6	5	3	1	2	2	—	1	1	31
Professional & scientific instruments	13	21	26	14	13	11	14	16	19	19	21	20	207
Group II total	8	7	9	9	12	10	15	14	8	12	10	9	123
Petroleum refining & extraction	2	—	—	—	1	1	1	3	1	2	3	—	14
Rubber products	—	—	—	—	2	1	1	2	—	—	1	1	8
Stone, clay, glass & concrete products	4	5	4	4	4	2	5	5	4	7	4	5	53
Fabricated metal products	—	1	—	—	2	2	1	1	1	—	1	1	10
Motor vehicles & other transportation equipment	2	1	5	5	3	4	7	3	2	3	1	2	38
Group III total	3	4	4	2	3	2	2	4	2	5	7	4	42
Food & kindred products	—	2	—	—	1	—	1	—	—	—	—	—	4
Textiles & apparel	—	—	1	—	—	—	—	—	—	1	1	—	3
Lumber, wood products & furniture	—	—	—	—	—	—	—	—	—	—	—	—	—
Paper & allied products	1	—	1	—	1	1	—	3	1	3	4	2	17
Primary metals	2	2	2	2	1	1	1	1	1	1	2	2	18

[1] *Industrial Research Magazine's* annual awards for the 100 "most significant new technical products of the year."

SOURCE: Battelle Columbus Laboratories, *Indicators of the Output of New Technological Products from Industry*, 1975. (A study commissioned specifically for this report.)

Table 4-19. Mean time in years between invention and innovation, by groups of R&D-intensive industries, 1953-73

R&D intensity	1953-73	1953-59	1960-66	1967-73
All manufacturing industries	7.3	7.8	6.9	7.2
Group I	6.3	6.1	6.8	5.9
Group II	8.4	8.5	7.3	9.3
Group III	11.1	12.1	([1])	12.0

[1] Insufficient number of innovations for determining mean.

SOURCE: Gellman Research Associates, Inc., *Indicators of International Trends in Technological Innovation*, 1975. (A study commissioned specifically for this report).

Table 4-20. "Radicalness" of major U.S. innovations, 1953-73

Basis of innovations	1953-73	1953-59	1960-66	1967-73
	Percent distribution by basis of innovations			
Total	100	100	100	100
Improvement of existing technology	41	45	38	41
Major technological advance	32	19	34	41
Radical breakthrough	27	35	29	18
	Number of innovations			
Total	208	62	80	66
Improvement of existing technology	85	28	30	27
Major technological advance	66	12	27	27
Radical breakthrough	57	22	23	12

NOTE: Detail may not add to totals because of rounding.

SOURCE: Gellman Research Associates, Inc., *Indicators of International Trends in Technological Innovation*, 1975. (A study commissioned specifically for this report).

Table 4-21. "Radicalness" of major U.S. innovations, by groups of R&D-intensive industries, 1953-62 and 1963-73

Basis of innovation and R&D intensity	1953-62	1963-73
	Percent distribution	
Total	100	100
Group I		
Improvement of existing technology	24	25
Major technological advance	20	30
Radical breakthrough	23	14
Group II		
Improvement of existing technology	13	9
Major technological advance	4	6
Radical breakthrough	4	7
Group III		
Improvement of existing technology	6	5
Major technological advance	1	1
Radical breakthrough	5	2
	Number of innovations	
Total	96	112
Group I		
Improvement of existing technology	23	28
Major technological advance	19	34
Radical breakthrough	22	16
Group II		
Improvement of existing technology	12	10
Major technological advance	4	7
Radical breakthrough	4	8
Group III		
Improvement of existing technology	6	6
Major technological advance	1	1
Radical breakthrough	5	2

NOTE: Detail may not add to totals because of rounding.

SOURCE: Gellman Research Associates, Inc., *Indicators of International Trends in Technological Innovation*, 1975. (A study commissioned specifically for this report).

Table 4-22. Sources of technology underlying major U.S. innovations, 1953-73

Source	Frequency[1]
Applied research	205
Basic research	109
Technology transfer[2]	77
Licensing	12
Purchase of "know-how"	8
Acquisition/merger	0

[1] Multiple responses were accepted.
[2] From within the innovating company.

SOURCE: Gellman Research Associates, Inc., *Indicators of International Trends in Technological Innovation*, 1975. (A study commissioned specifically for this report).

Table 4-23. Research underlying major U.S. innovations, by groups of R&D-intensive industries, 1953-73

R&D intensity	Total innovations	Applied research	Basic research
	Percent of innovations in each group		
All manufacturing industries	([1])	74	39
Group I	([1])	76	44
Group II	([1])	70	32
Group III	([1])	69	28
	Number		
All manufacturing industries	277	205	109
Group I	182	139	80
Group II	66	46	21
Group III	29	20	8

[1] Multiple responses were accepted; therefore, these percents add to more than 100 percent.

SOURCE: Gellman Research Associates, Inc., *Indicators of International Trends in Technological Innovation*, 1975. (A study commissioned specifically for this report).

Table 4-24. Research underlying major U.S. innovations and "radicalness" of innovations, 1953-73

"Radicalness" of innovations	Total innovations	Applied research	Basic research
	Percent of innovations in each category		
Improvement of existing technology	([1])	96	45
Major technological advance	([1])	94	48
Radical breakthrough	([1])	94	68
	Number		
Improvement of existing technology	80	77	36
Major technological advance	65	61	31
Radical breakthrough	53	50	36

[1] Multiple responses were accepted; therefore, these percents add to more than 100 percent.

SOURCE: Gellman Research Associates, Inc., *Indicators of International Trends in Technological Innovation*, 1975. (A study commissioned specifically for this report).

Table 5-1. Estimated percent distribution of doctoral scientists, by field, 1966-73

Field	Percent 1966	1968	1970	1973
Total	100	100	100	100
Physical scientists	45	44	42	31
Chemists	27	26	24	16
Physicists and astronomers	13	13	13	9
Earth scientists	5	5	4	5
Atmospheric scientists	1	1	1	(1)
Mathematical scientists	7	8	8	8
Life scientists	19	22	22	31
Biological scientists	17	20	19	25
Agricultural scientists	3	2	2	6
Psychologists	14	13	14	14
Social scientists	15	13	14	16
Economists	6	6	6	5
Sociologists and anthropologists	4	4	4	4
Other social scientists	4	4	4	8

NOTE: Detail may not add to totals because of rounding.

[1] Less than 0.5 percent.

SOURCE: National Science Foundation, special tabulations.

Table 5-2. Distribution of employed doctoral scientists and engineers, by employment sector, 1973

Employment sector	All doctoral scientists and engineers		Scientists		Engineers	
	Number	Percent[1]	Number	Percent[1]	Number	Percent[1]
Total	226,750	100	190,563	100	36,187	100
Business & industry	50,022	22	32,674	17	17,348	49
Educational institutions	132,692	59	119,670	64	13,022	37
Four-year universities and colleges	128,095	57	115,224	61	12,871	36
Two-year colleges	3,061	1	2,920	2	141	(2)
Elementary and secondary schools	1,536	1	1,526	1	10	(2)
Hospitals & clinics	5,714	3	5,651	3	63	(2)
Nonprofit organizations	7,853	4	6,562	3	1,291	4
Government	23,543	11	20,027	11	3,516	10
Federal	19,624	9	16,371	9	3,253	9
State	2,597	1	2,455	1	142	(2)
Other	1,322	1	1,201	1	121	(2)
Other employment sectors	3,390	2	2,964	2	426	1
Employment sector unreported	3,536	—	3,015	—	521	—

[1] Excluding those whose employment sector was not reported.
[2] Less than 0.5 percent.

NOTE: Detail may not add to totals because of rounding.
SOURCE: National Science Foundation, *Characteristics of Doctoral Scientists and Engineers in the United States, 1973,* Detailed Statistical Tables (NSF 75-312-A).

Table 5-3. Distribution of employed doctoral scientists and engineers, by primary work activity, 1973

Primary work activity	All doctoral scientists and engineers		Scientists		Engineers	
	Number	Percent[1]	Number	Percent[1]	Number	Percent[1]
Total	226,750	100	190,563	100	36,187	100
Research & development	69,509	33	56,325	32	13,184	38
Basic research	32,275	15	31,213	18	1,062	3
Applied research	28,654	14	21,604	12	7,050	21
Development & design	8,580	4	3,508	2	5,072	15
Management or administration	40,408	19	30,851	17	9,557	28
Of R&D	22,529	11	16,212	9	6,317	18
Other than R&D	12,097	6	10,049	6	2,048	6
Both	5,782	3	4,590	3	1,192	3
Teaching	81,728	39	72,770	41	8,958	26
Consulting	4,014	2	2,847	2	1,167	3
Sales	8,242	4	8,017	5	225	1
Other primary work activities	6,939	3	5,716	3	1,223	4
Primary work activity unreported	15,910	—	14,037	—	1,873	—

[1] Excluding those whose primary work activity was unreported.

NOTE: Detail may not add to totals because of rounding.

SOURCE: National Science Foundation, *Characteristics of Doctoral Scientists and Engineers in the United States, 1973,* Detailed Statistical Tables (NSF 75-312-A).

Table 5-4. Estimated percent distribution of doctoral scientists, by primary work activity, 1966-73

Primary work activity	1966	1968	1970	1973
Total	100	100	100	100
Research and development	42	40	38	32
Basic research	27	25	23	18
Applied research	13	14	14	12
Development	2	1	2	2
Management or administration	20	20	20	18
Of R&D	13	12	12	12
Other than R&D	7	8	8	6
Teaching	30	32	35	41
Other	8	8	7	9

NOTE: Detail may not add to totals because of rounding.

SOURCE: National Science Foundation, special tabulations.

Table 5-5. Scientists and engineers employed in universities and colleges, by field of employment, 1965-74

Field of employment	January					
	1965	1967	1969	1971	1973	1974
All scientists and engineers	178,904	212,855	246,183	273,775	282,631	288,085
Engineers	21,681	25,253	25,387	27,130	27,454	26,779
Aeronautical	1,127	1,360	1,357	1,469	1,469	1,215
Chemical	1,571	1,565	1,735	1,843	1,725	1,720
Civil	3,145	3,660	3,894	4,129	4,450	4,468
Electrical	5,478	6,563	6,803	6,885	6,936	6,451
Mechanical	4,108	4,638	4,812	5,387	5,220	4,884
Other engineers	6,252	7,467	6,786	7,417	7,654	8,041
Physical scientists	25,485	31,354	33,698	35,943	37,257	38,009
Chemists	10,684	12,961	14,201	14,688	15,427	16,058
Earth scientists[1]	4,005	5,111	5,549	6,500	6,943	7,457
Physicists	9,132	11,127	11,766	12,195	12,225	12,110
Other physical scientists	1,664	2,155	2,182	2,560	2,662	2,384
Mathematicians and computer scientists	13,680	17,776	22,495	24,548	24,931	26,970
Life scientists	75,775	87,347	97,206	110,274	112,919	115,801
Agricultural	13,507	14,950	15,150	18,039	15,232	14,307
Biological	24,281	27,419	29,257	31,808	33,777	35,431
Medical	37,987	44,978	52,799	60,427	63,910	66,063
Psychologists	9,430	11,358	14,780	16,806	19,070	19,760
Social scientists	32,853	39,767	52,617	59,074	61,000	60,766
Economists	7,932	9,662	10,402	11,263	11,408	11,932
Sociologists	6,261	7,558	9,451	11,323	12,634	12,871
Political scientists	5,919	7,190	7,919	8,938	9,803	9,834
Historians	NA	NA	14,427	15,871	16,416	15,802
Other social scientists	12,741	15,357	10,418	11,679	10,739	10,327

[1] Includes atmospheric scientists and oceanographers.

SOURCE: National Science Foundation, *Manpower Resources for Scientific Activities at Universities and Colleges, January 1974,* Detailed Statistical Tables (NSF 75-300-A).

Table 5-6. Scientists and engineers[1] employed in universities and colleges, by level of attainment, 1965-74

Level of attainment	January					
	1965	1967	1969	1971	1973	1974
Total	178,904	212,855	246,183	273,775	282,631	288,085
Ph.D. and Sc.D.	74,278	88,876	107,297	123,474	133,943	138,984
M.D. and D.D.S.	33,524	38,695	41,734	46,529	47,779	47,764
Master's	52,380	63,161	72,820	78,939	75,828	76,723
Bachelor's or equivalent	18,722	22,123	24,332	24,833	25,061	24,614

[1] Full-time and part-time.

SOURCE: National Science Foundation, *Manpower Resources for Scientific Activities at Universities and Colleges, January 1974,* Detailed Statistical Tables (NSF 75-300-A), and special tabulations.

Table 5-7. Number of academic scientists and engineers, by primary work activity, 1965-74

Primary work activity	January					
	1965	1967	1969	1971	1973	1974
Total	178,904	212,855	246,183	273,775	282,631	288,085
Teaching	121,991	147,846	174,623	200,317	216,200	223,038
Research and development	40,003	44,603	47,384	48,544	46,735	48,490
Other activities	16,910	20,406	24,176	24,914	19,696	16,557

SOURCE: National Science Foundation, *Manpower Resources for Scientific Activities at Universities and Colleges, January 1974*, Detailed Statistical Tables, (NSF 75-300-A), and earlier volumes.

Table 5-8. Tenured faculty as a percent of all faculty in doctorate-level science and engineering departments, by selected fields, 1974

Field	Percent with tenure
All science and engineering fields	70
Chemical engineering	81
Physics	78
Electrical engineering	77
Botany	77
Chemistry	77
Geology	75
Zoology	71
Biology	69
Economics	67
Mathematics	67
Biochemistry	66
Microbiology	65
Psychology	63
Sociology	60
Physiology	59

SOURCE: National Science Foundation, *Young and Senior Science and Engineering Faculty, 1974: Support, Research Participation, and Tenure* (NSF 75-301).

Table 5-9. Doctoral scientists and engineers, by age and type of employer, 1973

Age	Business and industry		Four-year colleges and universities		Federal Government	
	Number	Percent	Number	Percent	Number	Percent
Total	50,022	100	128,095	100	19,624	100
Under 30	1,976	4	6,087	5	999	5
30-34	11,855	24	29,234	23	4,067	21
35-39	10,201	20	24,960	19	3,683	19
40-44	8,117	16	20,626	16	3,108	16
45-49	6,445	13	17,129	13	2,890	15
50-54	5,696	11	13,253	10	2,295	12
55-59	3,412	7	8,572	7	1,493	8
60-64	1,600	3	5,090	4	672	4
65 or over	652	1	2,981	2	384	2
No report	68	([1])	163	([1])	11	([1])

[1] Less than 0.5 percent.

NOTE: Detail may not add to totals because of rounding.

SOURCE: National Science Foundation, *Characteristics of Doctoral Scientists and Engineers in the United States, 1973* (NSF 75-312).

Table 5-10. Postdoctorals and research assistants in science and engineering departments at doctorate-granting institutions, 1967-74

(Index: 1967 = 100)

	1967	1968	1969	1970	1971	1972	1973	1974
Postdoctorals	100	104	113	114	120	131	123	121
Research assistants	100	99	98	98	93	94	96	100

NOTE: The indices for 1967-71 are estimates based on applications submitted to NSF for its departmental traineeship program. Indices after 1971 were collected by the "Survey of Graduate Science Student Support and Postdoctorals" for matched departments.

SOURCE: National Science Foundation, special tabulations.

Table 5-11. Doctoral scientists and engineers by type of R&D activities and by field, 1973

Activity	Total	Physical scientists	Engineers	Mathematical scientists	Life scientists	Social scientists
Total	97,820	32,710	20,693	4,329	34,427	5,661
Research	60,929	21,288	8,112	2,733	25,231	3,565
Development	8,580	1,962	5,072	728	660	158
Management of R&D	28,311	9,460	7,509	868	8,536	1,938
	Percent distribution					
Total	100	33	21	4	35	6
Research	100	35	13	4	41	6
Development	100	23	59	8	8	2
Management of R&D	100	33	27	3	30	7

NOTE: Detail may not add to totals because of rounding.

SOURCE: National Science Foundation, *Characteristics of Doctoral Scientists and Engineers in the United States, 1973* (NSF 75-312).

Table 5-12. Doctoral R&D scientists and engineers, by type of employer, 1973

	Total	Business and industry	Educational institutions	Government	Other employers
All scientists and engineers	97,820	37,474	33,876	17,274	9,196
Scientists	77,127	23,734	31,040	14,625	7,728
Engineers	20,693	13,740	2,836	2,649	1,468
	Percent distribution				
All scientists and engineers	100	38	35	18	9
Scientists	100	31	40	19	10
Engineers	100	66	14	13	7

SOURCE: National Science Foundation, *Characteristics of Doctoral Scientists and Engineers in the United States, 1973* (NSF 75-312).

Table 5-13. Doctoral R&D scientists and engineers, by field and type of employer, 1973

Field	Total	Business and industry	Educational institutions	Government	Other employers
Total	97,820	37,474	33,876	17,274	9,196
Physical scientists	27,445	15,426	5,980	4,043	1,996
Mathematical scientists	4,329	1,476	1,967	629	257
Environmental scientists[1]	5,265	1,259	1,577	1,956	473
Engineers	20,693	13,740	2,836	2,649	1,468
Life scientists	34,427	5,133	18,480	6,870	3,944
Social scientists	5,661	440	3,036	1,127	1,058
	Percent distributions				
Total	100	38	35	18	9
Physical scientists	100	56	22	15	7
Mathematical scientists	100	34	45	15	6
Environmental scientists[1]	100	24	30	37	9
Engineers	100	66	14	13	7
Life scientists	100	15	54	20	12
Social scientists	100	8	54	20	19

[1] Includes earth scientists, oceanographers, and atmospheric scientists.

NOTE: Detail may not add to totals because of rounding.

SOURCE: National Science Foundation, *Characteristics of Doctoral Scientists and Engineers in the United States, 1973* (NSF 75-312).

Table 5-14. Young doctorate faculty[1] investigators[2] as a percent of all faculty investigators, by selected fields, 1968 and 1974

Selected fields	1968	1974
Biology	33	28
Chemistry	38	22
Economics	41	34
Electrical engineering	48	28
Mathematics	54	38
Physics	42	19
Psychology	45	40

[1] Those who had held doctorates seven years or less at the time of each study.
[2] Spending 20 percent of more of their time in research.

SOURCE: National Science Foundation, *Young and Senior Science and Engineering Faculty, 1974: Support, Research Participation, and Tenure* (NSF 75-302).

Table 5-15. R&D scientists and engineers[1] employed in industry, by source of R&D funds, January 1967 and January 1974

(In thousands)

Industry	Total		Federally supported		Company supported	
	1967	1974	1967	1974	1967	1974
Total	367.2	360.6	161.3	111.0	205.9	249.6
Electrical equipment and communication	98.6	94.7	51.9	39.3	46.7	55.4
Aircraft and missiles	100.4	70.3	80.3	47.7	20.1	22.6
Machinery	33.6	43.3	7.8	6.7	25.8	36.6
Chemicals and allied products	36.9	42.3	3.6	2.5	33.3	39.8
Motor vehicles and other transportation equipment	25.2	28.5	6.4	3.7	18.8	24.8
All other industries	72.5	81.5	11.3	11.1	61.2	70.4

[1] Full-time equivalent basis.

SOURCE: National Science Foundation, *Research and Development in Industry, 1973* (NSF 75-315).

Table 5-16. Average unemployment rates, 1963-74[1]

Year	Total labor force	Professional and technical workers	Scientists		Engineers	
			Total	Doctoral	Total	Doctoral
1963	5.7	1.9	NA	NA	1.2	NA
1964	5.1	1.8	NA	NA	1.5	NA
1965	4.6	1.5	NA	NA	1.1	NA
1966	3.9	1.3	.4	NA	.7	NA
1967	3.7	1.3	NA	NA	.6	NA
1968	3.6	1.2	.9	.5	.7	NA
1969	3.5	1.3	NA	NA	.8	NA
1970	5.0	2.0	1.6	.9	2.2	NA
1971	6.0	3.0	2.6	1.4	2.9	1.9
1972	5.6	2.4	NA	NA	2.0	NA
1973	4.9	2.2	NA	1.2	1.0	.8
1974	5.6	2.3	NA	NA	1.3	NA

[1] Not seasonally adjusted.

SOURCE: Department of Labor, Bureau of Labor Statistics, and National Science Foundation, special tabulations.

Table 5-17. Occupational preference of college freshmen, 1968-74

Probable career occupation	Percent distribution						
	1968	1969	1970	1971	1972	1973	1974
Total	100	100	100	100	100	100	100
Artist (including performer)	6	6	6	6	7	4	6
Business	11	11	11	11	11	16	13
Clergy	1	1	1	1	1	1	1
College teacher	1	1	1	1	1	1	1
Doctor (M.D. or D.D.S.)	4	3	4	4	6	6	5
Educator	24	22	19	15	12	9	8
Elementary	9	9	8	7	6	4	4
Secondary	14	13	11	9	7	5	4
Engineer	8	8	8	5	5	5	5
Farmer or forester	2	2	2	3	3	3	4
Health professional (non-M.D.)	4	4	5	6	7	8	9
Lawyer	3	4	4	4	5	5	4
Nurse	3	3	4	4	5	5	5
Research-scientist	3	3	3	3	2	3	2
Other occupation	20	22	22	24	23	23	26
Undecided	11	11	12	13	14	11	12

NOTE: Detail may not add to totals because of rounding.

SOURCE: American Council on Education and University of California, Los Angeles: *The American Freshman: National Norms*, annual series.

Table 5-18. Percent distribution of the college majors of National Merit Scholars, 1966-74

Field	1966	1967	1968	1969	1970	1971	1972	1973	1974
	Percent distribution								
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Science and engineering	62.3	63.8	66.6	66.6	68.6	68.1	69.1	68.3	69.8
Engineering	8.6	10.4	10.6	9.9	12.9	9.4	8.5	9.0	11.2
Science	53.7	53.5	56.0	56.7	55.7	58.7	60.7	59.3	58.6
Physical and natural sciences	36.2	36.6	37.0	36.2	36.9	36.4	33.5	32.6	32.4
Physical sciences	14.2	13.3	11.9	11.1	12.4	10.1	8.5	8.0	8.9
Chemistry	6.0	5.4	4.1	3.7	4.6	4.0	2.9	2.6	3.1
Physics	7.6	7.0	6.9	6.4	6.2	5.0	4.2	4.4	4.4
Other physical sciences	.6	.9	.9	1.0	1.7	1.1	1.5	1.0	1.4
Life sciences	6.2	5.2	3.3	4.3	3.2	4.2	4.1	4.4	4.6
Mathematics	14.1	15.4	12.2	12.2	11.8	12.8	10.1	10.1	7.8
Unspecified physical and natural sciences	1.7	2.7	9.6	8.5	9.5	9.3	10.8	10.2	11.1
Pre-medicine	5.2	4.4	5.8	6.4	5.9	7.2	11.0	11.3	10.1
Social sciences	12.3	12.4	13.2	14.1	12.9	15.2	16.1	15.4	16.1
All other fields and undecided	37.7	36.2	33.4	33.4	31.4	31.9	30.9	31.7	30.2
Health professions	1.5	1.0	.9	1.8	1.6	1.5	2.5	2.5	1.9
All other fields	24.1	23.3	28.2	27.6	26.1	26.3	24.9	25.6	23.5
Undecided	12.1	11.8	4.3	4.0	3.7	4.1	3.5	3.6	4.8

NOTE: Detail may not add to totals because of rounding.

SOURCE: National Merit Scholarship Corporation, *National Merit Scholarship Corporation Annual Report*, annual series.

Table 5-19a. Bachelor's and first-professional degrees awarded, by field, 1960-72

Year	All fields	Science and engineering: Total	Physical sciences	Engineering	Mathematical sciences	Life sciences	Social sciences	All other fields
1960	394,889	120,937	16,057	37,808	11,437	24,141	31,494	273,952
1961	401,784	121,660	15,500	35,866	13,127	23,900	33,267	280,124
1962	420,485	127,469	15,894	34,735	14,610	25,200	37,030	293,016
1963	450,592	135,964	16,276	33,458	16,128	27,801	42,308	314,628
1964	502,104	153,361	17,527	35,226	18,677	31,611	50,320	348,743
1965	538,930	164,936	17,916	36,795	19,668	34,842	55,715	373,994
1966	555,613	173,471	17,186	35,815	20,182	36,964	63,424	382,142
1967	594,862	187,849	17,794	36,188	21,530	39,408	72,929	407,013
1968	671,591	212,174	19,442	37,614	24,084	43,260	87,774	459,417
1969	769,683	244,519	21,591	41,553	28,263	48,713	104,399	525,164
1970	833,322	264,122	21,551	44,772	29,109	52,129	116,561	569,200
1971	884,386	271,176	21,549	45,387	27,306	51,461	125,473	613,210
1972	937,884	281,228	20,887	46,003	27,250	53,484	133,604	656,656

SOURCE: National Center for Educational Statistics, *Earned Degrees Conferred*, annual series, and National Science Foundation, special tabulations.

Table 5-19b. Percent distribution of all bachelor's and first-professional degrees, by field, 1960-72

Year	All fields	Science and engineering						All other fields
		Total	Physical sciences	Engineering	Mathematical sciences	Life sciences	Social sciences	
1960	100	31	4	10	3	6	8	69
1961	100	30	4	9	3	6	8	70
1962	100	30	4	8	4	6	9	70
1963	100	30	4	7	4	6	9	70
1964	100	31	4	7	4	6	10	69
1965	100	31	3	7	4	7	10	69
1966	100	31	3	6	4	7	11	69
1967	100	32	3	6	4	7	12	68
1968	100	32	3	6	4	6	13	68
1969	100	32	3	5	4	6	14	68
1970	100	32	3	5	4	6	14	68
1971	100	31	2	5	3	6	14	69
1972	100	30	2	5	3	6	14	70

NOTE: Detail may not add to totals because of rounding.

SOURCE: National Center for Educational Statistics, *Earned Degrees Conferred*, annual series, and National Science Foundation, special tabulations.

Table 5-20a. Enrollment for advanced degrees, by field, 1960-72

Year[1]	All fields	Science and engineering						All other fields
		Total	Physical sciences	Engineering	Mathematical sciences	Life sciences	Social sciences	
1960	314,349	120,638	25,707	36,636	11,770	19,715	26,810	193,711
1961	338,981	128,794	26,553	39,367	12,671	21,446	28,757	210,187
1962	373,845	142,433	28,591	43,850	14,121	23,953	31,918	231,412
1963	413,366	158,051	30,959	48,917	15,974	26,888	35,313	255,315
1964	477,535	178,123	34,061	54,318	18,805	30,787	40,152	299,412
1965	535,332	195,346	36,506	57,516	21,014	34,749	45,561	339,986
1966	583,000	207,049	37,950	58,338	23,150	37,007	50,604	375,951
1967	649,697	224,468	40,477	62,633	25,066	39,954	56,368	425,229
1968	703,745	234,661	40,937	63,662	26,840	41,676	61,546	469,084
1969	756,865	243,715	39,885	65,048	29,175	44,203	65,404	513,150
1970	816,207	252,159	40,113	64,788	30,608	46,260	70,390	564,048
1971	836,294	246,100	38,928	59,321	28,847	47,662	71,342	590,194
1972	858,580	242,988	36,047	55,847	28,064	49,118	73,912	615,592

SOURCE: National Center for Educational Statistics, *Students Enrolled for Advanced Degrees*, annual series.

Table 5-20b. Percent distribution of enrollments for advanced degrees, by field, 1960-72

Year[1]	All fields	Science and engineering							All other fields
		Total	Physical sciences	Engineering	Mathematical sciences	Life sciences	Social sciences		
1960	100	38	8	12	4	6	9		62
1961	100	38	8	12	4	6	9		62
1962	100	38	8	12	4	6	9		62
1963	100	38	8	12	4	7	9		62
1964	100	37	7	11	4	6	8		63
1965	100	37	9	11	4	7	9		63
1966	100	36	7	10	4	6	9		64
1967	100	35	6	10	4	6	9		65
1968	100	33	6	9	4	6	9		67
1969	100	32	5	9	4	6	9		68
1970	100	31	5	8	4	6	9		69
1971	100	29	5	7	3	6	9		71
1972	100	28	4	7	3	6	9		72

[1] Data as of fall terms.

NOTE: Detail may not add to totals because of rounding.

SOURCE: National Center for Educational Statistics, *Students Enrolled for Advanced Degrees*, annual series.

Table 5-21a. Master's degrees awarded, by field, 1960-72

Year	All fields	Science and engineering						All other fields
		Total	Physical sciences	Engineering	Mathematical sciences	Life sciences	Social sciences	
1960	74,497	20,012	3,387	7,159	1,765	3,751	3,950	54,485
1961	78,269	22,786	3,799	8,178	2,238	4,085	4,486	55,483
1962	84,889	25,146	3,929	8,909	2,680	4,672	4,956	59,743
1963	91,418	27,367	4,132	9,635	3,323	4,718	5,559	64,051
1964	101,122	30,271	4,567	10,827	3,603	5,357	5,917	70,851
1965	112,195	33,835	4,918	12,056	4,294	5,978	6,589	78,360
1966	140,772	38,083	4,992	13,678	5,610	6,666	7,737	102,689
1967	157,892	41,800	5,412	13,885	5,733	7,465	9,305	116,092
1968	177,150	45,425	5,508	15,188	6,081	8,315	10,333	131,725
1969	194,414	48,425	5,911	15,243	6,735	8,809	11,727	145,989
1970	209,387	49,318	5,948	15,597	7,107	8,590	12,076	160,069
1971	231,486	50,624	6,386	16,347	6,789	8,320	12,782	180,862
1972	252,774	53,567	6,307	16,802	7,186	8,914	14,358	199,207

SOURCE: National Center for Educational Statistics, *Earned Degrees Conferred*, and National Science Foundation, special tabulations.

Table 5-21b. Percent distribution of all master's degrees, by field, 1960-72

Year	All fields	Science and engineering						All other fields
		Total	Physical sciences	Engineering	Mathematical sciences	Life sciences	Social sciences	
1960	100	27	5	10	2	5	5	73
1961	100	29	5	10	3	5	6	71
1962	100	30	5	11	3	6	6	70
1963	100	30	5	11	4	5	6	70
1964	100	30	5	11	4	5	6	70
1965	100	30	4	11	4	5	6	70
1966	100	27	4	10	4	5	6	73
1967	100	26	3	9	4	5	6	74
1968	100	26	3	9	3	5	6	74
1969	100	25	3	8	4	5	6	75
1970	100	24	3	7	3	4	6	76
1971	100	22	3	7	3	4	6	78
1972	100	21	3	7	3	4	6	79

NOTE: Detail may not add to totals because of rounding.

SOURCE: National Center for Educational Statistics, *Earned Degrees Conferred*, and National Science Foundation, special tabulations.

Table 5-22. Doctoral degrees awarded, 1965-74

Year	All fields	Science and engineering						All other fields
		Total	Physical sciences	Engineering	Mathematical sciences	Life sciences	Social sciences	
1965	16,340	10,477	2,865	2,073	685	2,539	2,315	5,863
1966	17,953	11,456	3,058	2,299	769	2,712	2,618	6,497
1967	20,384	12,982	3,502	2,603	830	2,967	3,080	7,402
1968	22,916	14,411	3,667	2,847	970	3,501	3,426	8,505
1969	25,724	15,949	3,910	3,249	1,064	3,796	3,930	9,775
1970	29,475	17,731	4,400	3,432	1,222	4,163	4,514	11,744
1971	31,772	18,880	4,494	3,495	1,236	4,533	5,122	12,892
1972	33,001	18,940	4,226	3,475	1,281	4,505	5,453	14,061
1973	33,727	18,948	4,016	3,338	1,222	4,574	5,798	14,779
1974	33,000	18,316	3,696	3,144	1,196	4,407	5,873	14,684

SOURCE: National Academy of Sciences, *Doctorate Recipients from U.S. Universities*, annual series.

Table 5-23a. Women science and engineering doctorate recipients, by field, 1965-74

Year	Total	Physical sciences	Engi-neering	Mathe-matical sciences	Life sciences[2]	Social sciences
1965	744	127	7	50	263	297
1966	911	132	8	48	326	397
1967	1,086	161	9	48	401	467
1968	1,295	185	12	47	483	568
1969	1,472	205	10	56	537	664
1970	1,626	243	15	77	538	753
1971	1,929	244	16	96	656	917
1972	2,101	269	21	96	680	1,035
1973	2,446	257	45	119	795	1,230
1974	2,590	260	34	115	784	1,397

Table 5-23b. Women as a percent of total science and engineering doctorate recipients, by field, 1965-74

Year	Total	Physical sciences	Engi-neering	Mathe-matical sciences	Life sciences[2]	Social sciences
1965	7	4	([1])	7	10	13
1966	8	4	([1])	6	12	15
1967	8	5	([1])	6	14	15
1968	9	5	([1])	5	14	17
1969	9	5	([1])	5	14	17
1970	9	6	([1])	6	13	17
1971	10	5	1	8	15	18
1972	11	6	1	7	15	19
1973	13	6	1	10	17	21
1974	14	7	1	10	18	24

[1] Less than 0.5 percent.
[2] Includes environmental sciences.

SOURCE: National Academy of Sciences, *Doctorate Recipients from U.S. Universities*, annual series.

Table 5-24. Minority representation among scientists and engineers, by field, 1972

	Total scientists and engineers (thousands)	Minorities as percent of total			
		All minorities	Black	Oriental	Other non-white
Total	1,336.5	4.0	1.2	2.4	0.4
Engineers	840.3	3.4	.8	2.3	.3
Mathematical scientists	31.1	8.3	4.5	3.2	.6
Computer scientists	112.1	3.5	1.5	1.5	.5
Life scientists	77.2	5.5	1.7	2.5	1.3
Physical scientists	179.8	5.8	1.7	3.8	.3
Social scientists and psychologists	95.9	4.3	2.5	1.5	.3

NOTE: Detail may not add to totals because of rounding.

SOURCE: National Science Foundation, special tabulations.

SUPPLEMENTARY COMMENTS

Dr. Saunders Mac Lane has contributed the following technical comments on the validity of the sampling procedures underlying some of the material in Chapter One. While some of the questions have been dealt with in the text itself, the National Science Board believes they should be presented in their entirety here and expresses its appreciation to Dr. Mac Lane for his observations.

There are real uncertainties and difficulties in interpreting one of the figures and one of the tables in Chapter 1.

Figure 1-7, on page 14, gives the percent distribution of scientific literature by selected field for each of six countries. As the accompanying text indicates, it is hoped that these results will indicate approximately the way in which these countries differ in their emphasis on various fields of scientific research. However, this interpretation depends on whether the data are representative. The data came from a count of articles, notes, and reviews in a sample of 2,121 scientific journals. This sample is essentially the list of journals currently used by the *Science Citation Index* and chosen from approximately 26,000 science and technology journals currently published in the world. Clearly the distribution of this data depends on the choice of the sample. If in a given country the sample over-represents journals in one science, say chemistry, then the percentage over-represents the emphasis of that country on chemistry. At present unfortunately no real evidence is available as to whether the sample is representative. There is even evidence that the sample is not representative as of certain fields. One such is mathematics (not represented in Figure 1-7). The 2,121 journals include 122 journals in mathematics. Among them at least 31 are published in the United States and only seven in Russia. This is an unbalanced representation because this same report in table 1-6 indicates correctly that the U.S. and the U.S.S.R. each publish about 30 percent of the total world literature in mathematics. Hence any percent emphasis of U.S.S.R. on mathematics calculated from these data would be wrong. This same difficulty may well occur in other fields.

Page 13 gives a small table of the CITATION INDICES of selected scientific literature by selected fields. This citation index is a ratio calculated from the same 2,121 journals; the percentage of all citations in the field which are citations of the publications of the country in question, is divided by the percentage of articles in the field published by that country. These citation indices produce a rank order of the six countries in each of the six fields of science. In five of these six fields, the U.S. ranks first and the U.S.S.R. ranks last, while in four of these six fields France ranks next to last.

Before interpreting these rankings one should recognize the limitations of this calculation. In the first place, it depends on the representative character of the sample of journals used; the indications above are that this sample may not be representative. Secondly, it depends on citations and citations in turn depend on the availability of the literature to cite. It is evidently much easier to cite a paper written in your own language and present in your own university or city library. This fact, plus the general use of the English language, may have a lot to do with the ranking of Russia, since many Russian journals are not extensively distributed, many Western scientists can't read Russian, and many Russians may not see Western journals.

I have not been able to quantify these effects. However, table 1-7b in the appendix does indicate a self-citation index (e.g., Russian papers cited in other Russian papers). In each of six fields of science Russia has by far the highest self-citation index, while in chemistry it is outranked only by West Germany and in engineering only by France. These indices do suggest one possible effect upon citation rates.

Citation rates also depend on the scientific habits of the country in question. For example, French science in several fields is remarkable because there are relatively few scientists, including many of exceptional quality and insight; such a small-scale, high quality effort would be swamped in a citation index. Moreover, much of French scientific publication appears in the *Comptes Rendus* of the French Academy of Sciences. Notes published there are limited to four pages. This results in many scientific papers, each with little room for citations. Such a publication habit, to say nothing of the centralization of French science in Paris, means that the citation indices may not properly represent the balance or quality of French science.

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